NAVIGATION

HAROLD JACOBY

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NAVIGATION

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SECOND EDITION

WITH A CHAPTER ON COMPASS ADJUSTING AND A COLLECTION OF MISCELLANEOUS EXAMPLES

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To

MACLEAR JACOBY

QUARTERMASTER,* THIRD CLASS, U. S. N.
ENLISTED FOR THE PERIOD OF THE WAR
THIS VOLUME IS OFFERED AS
A MARK OF RESPECT
BY HIS FATHER

* Commissioned Ensign, U. S. N. R. F., September, 1917

PREFACE

THE present volume was undertaken with certain very definite aims. In the first place, it is intended to be complete in itself, so that it should be possible to navigate a ship in any ocean not very near the north or south pole without other books or tabular works, excepting only the nautical almanac for the year in which the voyage is made. To attain this end without unduly extending the size of the volume, certain essential nautical tables have been abridged; but all are given in sufficiently extended form to permit of actual navigation with their aid; and they are especially suitable for beginners, who can here attain the necessary knowledge with less effort than would be necessary with more bulky volumes. In cases where very extended tables are convenient, they are mentioned in the text.

In the second place, the author has not assumed that the reader possesses formal mathematical and astronomical knowledge, or desires to possess such knowledge. Whenever methods of navigation require for their demonstration an understanding of spherical trigonometry, or some other branch of formal mathematical science, such demonstrations have been replaced with incomplete or "outline" demonstrations designed for the non-mathematical reader. Practical methods are fully explained; and an attempt has always been made so to word the explanations that the reader, even the beginner, will understand his problem, and will know what he is doing, and why he does it.

The requirements of those who may study without a teacher have received constant and special attention. To meet these requirements the whole subject is presented in

a somewhat informal manner; such topics as the use of logarithms, or the principles on which all mathematical tables are constructed — these less attractive parts of the subject are not presented in a special chapter, but are described in a sort of digression, when needed in the discussion of an actual navigational problem.

Finally, to further simplify and condense his material, the author has made no attempt to include every method that can possibly be used to navigate a ship, or that ever has been used to navigate a ship; his purpose has been rather to limit the volume to the methods at present thought best by the most reliable modern authorities.

Other books on navigation have been used freely, especially in the preparation of the tables. Among these, that admirable encyclopedia of navigation, known as "Bowditch," published by the Hydrographic Office, United States Navy, and Kelvin's "Tables for Sumner's Method at Sea" have been found of the greatest help.

Miss Dorothy W. Block, Instructor of Astronomy in Hunter College, New York, has helped with great energy in the preparation of the tables and the correction of the text. It is hoped that such errors as may now remain in the book are few in number.

H. J.

Columbia University,
August, 1917.

PREFATORY NOTE TO THE SECOND EDITION

To meet the wishes of certain young navigators, this edition has an added chapter on the adjustment of correctors in a compensated compass binnacle, and also a collection of new problems and examples.

H. J.

February, 1918.

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LIST OF ABBREVIATIONS

Used in the Present Volume

Alt.	for altitude;
App.	for apparent;
Arg. diff.	for argument difference;
Cf.	for compare;
Chron.	for chronometer;
Comp'd	for computed;
Cos	for cosine;
Cot	for cotangent;
Csc	for cosecant;
C. – W.	for chronometer *minus* watch;
Dec.	for declination;
Dep.	for departure;
Dist.	for distance;
D. R.	for dead reckoning;
Eq.	for equation of time;
G. A. T.	for Greenwich apparent time;
G. M. T.	for Greenwich mean time;
Hav.	for haversine;
H. D.	for hourly difference;
Int. diff.	for interpolation difference;
Lat.	for latitude;
Lat. diff.	for latitude difference;
Log	for logarithm;
Long.	for longitude;
Long. diff.	for longitude difference;
Mer. lat. diff.	for meridional latitude difference;
Obs'd	for observed;
p	for polar distance;
R. A.	for right ascension;
s	for half sum;
Sec	for secant;
Sin	for sine;
T	for ship's apparent solar time (or star's hour-angle);
Tab. diff.	for tabular difference;
Tan	for tangent.

NAVIGATION

CHAPTER I

THE FUNDAMENTAL PROBLEM OF NAVIGATION

To find one's way in a ship across the trackless ocean is our problem. Most people would like to know how it is solved; nor is the solution very difficult to understand when set forth in simple language and without too great wealth of technical detail. We hope the reader will find this to be the case after a study of the following pages.

Our fundamental problem can be more fully stated quite easily. It consists in the determination of a ship's location on the earth's surface at any given moment. If this location can be determined, it becomes a comparatively easy matter to ascertain the direction (north, south, northeast, southeast, etc.) in which the ship must be steered in order to reach her port of destination. For the location of the port of destination on the earth's surface is of course also known: and if we know where the ship and her destined port both are, we can easily find the right course for the helmsman.

With the fundamental problem stated in this way, it would almost seem as if there were really no such problem in existence. For when the ship begins her voyage, she is necessarily in a known port. Knowing also the port to which she is to go, we should be able to determine her proper course from the one known port to the other. This course being then steered, no further navigational proceedings would be required. But this reasoning is incorrect, because a ship

does not actually advance across the ocean in exactly the direction in which she is steered. Ocean currents deflect her; and the action of a strong wind blowing against one of her sides will have a similar effect. Currents and winds cannot be predicted with accuracy: and so it becomes necessary to re-determine the ship's position frequently at sea. This should be done at least once daily if possible; and when it has been done, the mariner can take a new "departure," as he calls it, and lay a new course for his intended port. Thus the effect of ocean currents, etc., can be eliminated, and the voyage made as safely as if they did not exist.

Now this determination of the ship's position at sea, and when out of sight of land, is strictly an astronomical problem. It can be solved by means of astronomical observations, and in no other way. But before giving an outline of how this is done, let us first see what is meant by the words "ship's position at sea." How can we describe a ship's position so that one mariner could tell another where she is located, and thus enable the second mariner to find her?

To thus indicate the point on the earth's surface occupied by the ship has a certain similarity with giving the address of a house in a city. Such a city address always consists of two separate statements; as, for instance, the name of a street and the number of the house. An address cannot be given completely unless two different facts are stated. They need not necessarily be a street name and a street number: we can equally well designate such an address by stating that the house is at the corner of a certain street and a certain avenue. But here also the address is made up of two separate facts.

This form of stating an address as the intersection of a certain street and avenue is the form having the closest resemblance to the method of the navigator. If the city avenues are supposed to run north and south, and the streets

east and west, as they do in New York (approximately), the analogy with navigation will be almost perfect.

For the navigator imagines the earth covered with a network consisting of "avenues," running north and south, and "streets," running east and west. He calls the "avenues" meridians of longitude, and the "streets" parallels of latitude. Then he designates the position of a ship on the ocean by stating that it is at the intersection of a certain meridian of longitude and parallel of latitude. There are 360 such meridians of longitude: each begins at the terrestrial equator, and runs north and south from there to the north and south poles of the earth. Of the latitude parallels there are 180.[1] They all run east and west, parallel to the terrestrial equator; 90 are between the equator and the north pole, and the other 90 between the equator and the south pole.

One of the longitude meridians (that passing through Greenwich, England) is chosen arbitrarily as the starting point for counting longitude meridians. To this initial meridian is assigned the number 0, and the other meridians are numbered successively 1, 2, 3, etc. So numbered, the meridians are called "degrees" of longitude; the third one, for instance, being written 3°. The meridians may be counted either eastward or westward from Greenwich, a ship on the 20th meridian west of Greenwich, for instance, being in longitude 20° west.

The latitude parallels are similarly counted north and south from the equator; and if the above ship were on the 40th latitude parallel north of the equator, her complete "address," or position at sea, would be long. 20° W.; lat. 40° N.

Of course a ship would only rarely be located exactly at the intersection of a meridian and parallel. Therefore, the space between any two successive meridians and between any two successive parallels is subdivided into 60 parts, called minutes of arc. Thus the above ship, if halfway

[1] Including the equator twice, but excluding the two poles.

between a pair of meridians and also halfway between a pair of parallels, might be in longitude 20° 30′ west, and in latitude 40° 30′ north. This would be written long. 20° 30′ W.; lat. 40° 30′ N.

Each minute of longitude and latitude is further subdivided, when extreme accuracy is required, into 60 seconds; so that if the ship were a little to the north and a little to the west of the above position, she might, for instance, be in long. 20° 30′ 26″ W.; lat. 40° 30′ 10″ N.

These meridians and parallels, or longitude and latitude lines, appear on many maps and charts as straight lines, or at least as lines only slightly curved. But being all lines imagined drawn on the earth, which is almost an exact sphere or round ball, they must really all be circles. Thus, the terrestrial equator is really a big circle, girdling the earth, and divided into 360 equal parts, or degrees. At each of the division points a meridian starts northward toward the pole. This meridian is also a big circle perpendicular to the equator. The distance along the meridian from the equator to the pole is divided into 90 equal parts or degrees, and the whole distance from equator to pole is one quarter of a complete circumference of the earth. The 90 degrees, from equator to pole, thus representing one quarter of a circumference of the earth, a complete circumference contains 4×90, or 360 degrees, the same as the equator. So the degrees measured along the meridians are equal to the degrees measured along the equator. The former are degrees of latitude, the latter degrees of longitude; and degrees of latitude are equal to degrees of longitude, when the latter are measured along the equator. The length of each degree is then 60 nautical miles.

Having thus indicated what is meant by a ship's position in latitude and longitude, we shall next describe in outline how such a position may be determined by observation. If the ship is within sight of a coast-line, there will probably

be some lighthouse, or other "aid to navigation," in view, from which the navigator can ascertain where he is. Methods for doing this are described later (p. 53). But when the ship is really at sea, with no land in sight, real deep-sea methods must be employed.

These methods, when the weather is clear, always include an observation of the sun or some other heavenly body. When the weather does not permit such observations, the mariner can still find his position approximately by means of "dead reckoning" (abbreviated, D. R.). This process will be described in detail in the next chapter; but we can already state that it consists in a calculation based on his astronomic observation of latest date. Knowing where the ship was the last time he observed the sun, and also knowing both the direction in which he has steered and the (approximate) speed of the ship, the navigator can calculate (also approximately) the location of the point he has reached.

Even when astronomical observations are made, the D. R. calculation is always carried out, because the navigator is always anxious to know how nearly correct his D. R. result would have been, if the day had been cloudy. Furthermore, this result also acts as a check on the astronomical work, and tends to increase the navigator's confidence in the correctness of his final result as to the ship's location.

The manner in which the ship's position is found from astronomic observations will of course be explained in detail later. It is all done with an instrument called a sextant. This is merely a contrivance with which the navigator can measure how high the sun (or other heavenly body) is in the sky at any moment. The sun is highest in the sky daily at noon, but it is not equally high on different days in the year. Nor is it equally high on the same date in different latitudes. Thus, by measuring with the sextant how high it is on any particular date at noon, as seen from the ship, the navigator learns the terrestrial latitude in which the ship is located.

Similar sextant observations made at other suitable times during the day, when combined with exact readings taken from an accurate chronometer such as every ocean-going ship carries, will similarly make the ship's longitude known. All this will of course be explained in full detail in later chapters.

CHAPTER II

DEAD RECKONING WITHOUT LOGARITHMS

As we have seen (p. 5), this is a process by means of which the mariner can calculate a ship's position in latitude

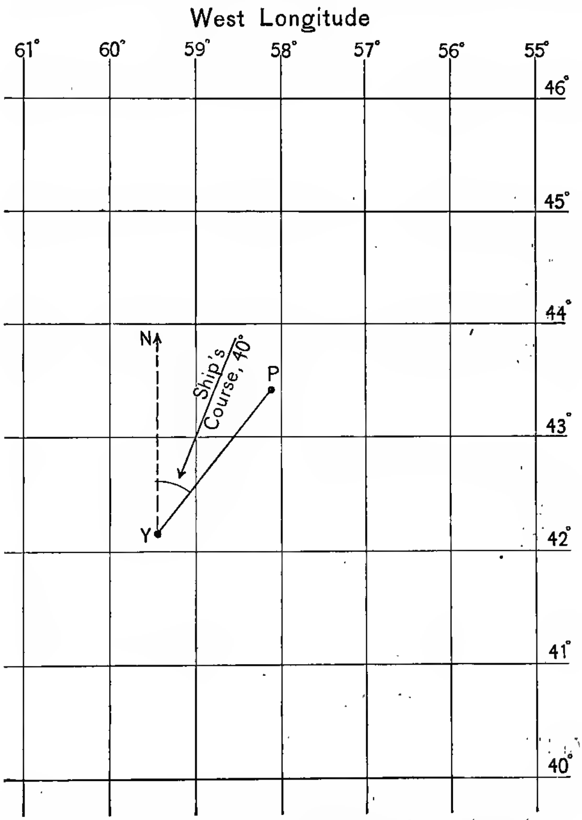

FIG. 1.—Dead Reckoning. (Diagram not drawn to scale.)

and longitude, without special astronomic observations of any kind. In the accompanying Fig. 1, which represents a portion of a chart of the North Atlantic, a ship's position at noon is shown at the point *Y*. This point we will call the ship's "initial position," in discussing our present problem. We will suppose that it was correctly obtained by astronomic observations, and that these showed the ship at *Y* to be in lat. 42° 11′ N. and long. 59° 28′ W. from Greenwich. Sometime in the afternoon, having traveled a distance estimated from the known speed of the ship as 63 miles, and having "made good" this distance in the direction *YP*, the ship arrives at *P*. This point *P* we will call the ship's "final position"; and our problem now is to find its latitude and longitude.

This problem may be called the first fundamental dead-reckoning problem. The second and remaining fundamental problem is the converse of the first, and may be stated as follows: having given the latitude and longitude of the initial point *Y*, as occupied by the ship, and also the latitude and longitude of the final point *P*, it is required to find the distance from *Y* to *P* in miles, and also the direction of the line *YP*.[1]

To understand these two problems properly it is next necessary to explain how we may define the words "direction *YP*." This is done by referring the line *YP* to the direction of the arrow shown in the figure. This arrow is parallel to the longitude meridians on the chart, and therefore points due north. The angle between the arrow *YN* and the line *YP* is marked in the figure, and is called the "ship's course." This angle is really the difference in direction of the two lines *YN* and *YP*. The point *Y* is called the "vertex" of the angle, and all angles are designated

[1] We think it advisable to place these two important converse problems together, and to call them both problems of dead reckoning, though many writers on navigation confine the phrase "dead reckoning" to the first fundamental problem alone.

by three letters, the letter belonging to the vertex being placed between the other two; in this case the angle is called either *NYP* or *PYN*.

Now let us draw a line *PQ* (fig. 2), from *P* to *NY*, and perpendicular to *NY*. Then the motion of the ship from *Y* to *P* will have carried her north of the point *Y* by a distance equal to *YQ*, and east of the point *Y* by a distance equal to *QP*. This is not *strictly* true, unless the earth's surface, throughout the small area involved in the present problem, can be regarded as a flat surface. Such a flat surface is called in geometry a "plane" surface; and these calculations therefore belong to that part of navigation which is called "plane sailing." Plane-sailing calculations are easy calculations, and they are generally sufficiently accurate for the purposes of the navigator.

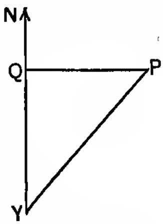

FIG. 2.—Dead Reckoning.

The ship's course, being thus an angle, must be designated by means of a unit of measure suitable for measuring angles. For this purpose the degrees and minutes already used for longitude and latitude (p. 3) are usually employed. Fig. 3 shows that a latitude, for instance, is really an angle, and must therefore also be measured in degrees. *P* is the earth's pole, *PQ* a meridian, and the latitude of the observer at *O* is the angle *OCQ*, here about 40°.

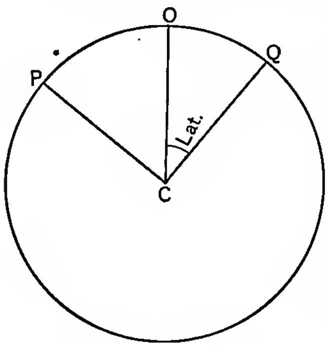

FIG. 3.—Latitude Angle.

So it is clear that the ship's course *NYP* (figs. 1 and 2) will be measured in degrees. Minutes are not really needed in measuring courses, as they are in measuring latitudes; the nearest whole degree is always accurate enough, because

it is never possible to steer a ship on her proper course with absolute exactness. In fact, many mariners use a still less precise method of measuring courses by means of "the points of the compass." (See p. 40.)

Resuming our two fundamental problems (p. 8), let us now begin with the first one, and proceed to find the latitude and longitude of the point *P* (figs. 1 and 2). To solve this problem, we must not only know the distance *YP* (63 miles), as traveled by the ship, but also the number of degrees in the course angle *NYP*. Let us suppose this course angle happens also to be 40°. The problem then appears as shown in Fig. 4. We now know the distance *YP* and the angle *QYP*. Evidently the next step is to find the distances *QY* and *QP*. *QY*, in our present problem, is called a "latitude difference" and *QP* is called a "departure."

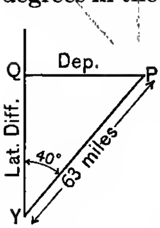

FIG. 4.—Dead Reckoning.

To find the "latitude difference" and "departure" from the course angle and distance we may either use that branch of mathematics called plane trigonometry, or we may find them from a special navigation table, called a "traverse table." Our Table 1 (beginning p. 154) is such a table.

Before[1] beginning its use it will be well for the reader to note in general that *all* mathematical tables consist of two sets of numbers. The first set of numbers are called "arguments" of the table, and the second set are called "tabular numbers." The main object of the table is to furnish us with the proper tabular number when we know the proper argument.

The ordinary multiplication table is a good example of a mathematical table. It is usually written as follows and

[1] The beginner may find it advisable, on a first reading of the book, to omit this explanation of mathematical tables, returning later when he finds a reference to it in the text. The dead reckoning problem under discussion is resumed on p. 13.

it affords a good opportunity of studying the principles underlying all mathematical tables in a case so simple as to offer no difficulty.

MULTIPLICATION TABLE

(to illustrate "argument" and "tabular number")

	2	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1	2	3	4	5	6	7	8	9	10	11	12
2	4	6	8	10	12	14	16	18	20	22	24
3	6	9	12	15	18	21	24	27	30	33	36
4	8	12	16	20	24	28	32	36	40	44	48
5	10	15	20	25	30	35	40	45	50	55	60
6	12	18	24	30	36	42	48*	54	60	66	72
7	14	21	28	35	42	49	56	63	70	77	84
8	16	24	32	40	48	56	64	72	80	88	96
9	18	27	36	45	54	63	72	81	90	99	108
10	20	30	40	50	60	70	80	90	100	110	120
11	22	33	44	55	66	77	88	99	110	121	132
12	24	36	48	60	72	84	96	108	120	132	144

In this table the arguments are printed in heavy type and are contained in the left-hand column and the topmost horizontal line. In using the table, these arguments are given in pairs, being always the pair of numbers to be multiplied. In fact, in the case of most tables, the arguments are thus given in pairs, though there are some tables with but a single argument. In the present case one number from the pair of arguments will be found in the left-hand column, the other in the top horizontal line. Thus, if we wish to multiply 6 and 8, these two numbers constitute the pair of arguments. We find the right line (belonging to 6) and column (belonging to 8), and the tabular number 48 (marked with a *) occurs at the intersection of the 6-line and the 8-column. If the pair of arguments are taken in the order 8×6 instead of 6×8, we should use the 8-line and the 6-column, again finding the required product (48) as the tabular number at the intersection.

Sometimes the given arguments cannot be found directly in the table. Thus we might wish to multiply $6\frac{1}{2}$ (written 6.5) by 8. Evidently the proper tabular number would be halfway between the 6×8 tabular number (48) and the 7×8 tabular number (56). The correct answer would therefore be 52. This process, by which the tabular number 52 is obtained, is called "interpolation." The example $6\frac{1}{2} \times 8$ is an extremely simple one. When less easy ones occur, the interpolation is best made as follows: we ascertain by subtraction how much the tabular number increases while the argument changes from 6 to 7. This increase is here 8, because the tabular number changes from 48 to 56 in the 8-column, while the argument in the left-hand column changes from 6 to 7. This increase of 8 in the tabular number is called a "tabular difference." We now compare the given argument (6.5) with the nearest argument (6) occurring in the left-hand column of arguments, and find an "argument difference" of 0.5 (being 6.5 *minus* 6). Since this "argument difference" is 0.5, we must evidently take 0.5×8 (8 being the tabular difference), and increase the tabular number 48 by 0.5×8, or 4. This again brings us to 52. Similar examples are:

$$(1)\ 5.3 \times 4 = 21.2;\quad (2)\ 7.7 \times 8 = 61.6.$$

In example (1) the tabular numbers are 20 and 24; the tabular difference is 4. $0.3 \times 4 = 1.2$; $20 + 1.2 = 21.2$, the answer. Both examples may be verified, of course, by ordinary multiplication.

When both given arguments contain fractions, as, for instance, 5.3×8.4, the resulting "double interpolation" is so complicated as to be of little practical use to the navigator.

To make this general explanation of mathematical tables complete, it remains to show how they can be used in an inverse manner; *i.e.* to find the argument from the tabular

number. Thus, if we were told that the tabular number is 48, and one argument 8, an inspection of the table would at once show that the other argument must be 6. In this way the table might be used for division as well as multiplication; and interpolation would evidently also be possible. Many mathematical tables must frequently be thus used in an inverse manner.

Having thus explained the peculiarities of mathematical tables, we return to our dead-reckoning problem and its solution by means of the traverse table (p. 154).

Referring to that table we find a column (p. 167), headed 40°, the course angle of our present problem. On the left-hand side of the page we find the given distance, 63. Then, opposite the distance 63, and under 40°, we find the latitude difference (abbreviated, "Lat.") and the departure (abbreviated, "Dep.") to be:

lat. = 48.3, dep. = 40.5.

The following are additional examples for practice:

Given: dist., 84, course 26°; *Ans.*, lat. = 75.5, dep. = 36.8.
Given: dist., 28, course 11°; *Ans.*, lat. = 27.5, dep. = 5.3.

When the course is between 1° and 45° the course angle will be found in Table 1 at the head of the column: but when the course is between 45° and 90°, it appears at the foot of the column. In the latter case, the tabular lat. and dep. are to be taken from the columns having "Lat." and "Dep." at the foot instead of the top of the column. Examples follow:

Given: dist., 63, course 50°; *Ans.*, lat. = 40.5, dep. = 48.3.
Given: dist., 84, course 64°; *Ans.*, lat. = 36.8, dep. = 75.5.
Given: dist., 28, course 52°; *Ans.*, lat. = 17.2, dep. = 22.1,

In addition to the course angles from 1° to 90°, three additional angles are given in parentheses at the top and foot of each column. Thus, with the course angle 30° appear also 150°, 210°, 330°. This simply means that the latitudes

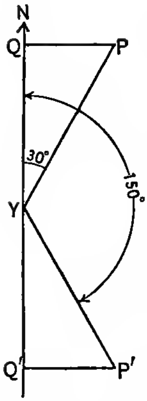

FIG. 5.—Departures for 30° and 150°.

and departures are the same for these four course angles. The accompanying Fig. 5 shows, for instance, that the departures QP and $Q'P'$ are equal for 30° and 150° courses if the two distances YP and YP' are alike.

It will be noticed also that our traverse table always gives distances from 1 to 50 on a left-hand page, and from 50 to 100 on a right-hand page. When distances larger than 100 occur, it is necessary to use the 100, 200, etc., given on the lower part of each page. If, for instance, we require the latitude and departure for a distance 363 miles, course 40°, we turn again to the 40° column, and find (near the bottom of the page):

For	300 miles,	lat. = 229.8,	dep. = 192.8
and (in the usual way) for	63 miles,	lat. = 48.3,	dep. = 40.5
Sums,	363	= 278.1	233.3

Consequently, for dist. 363, course 40°, lat. = 278.1, dep. = 233.3.

Other examples are:

Course 25°, dist., 452; lat. = 409.6, dep. = 191.0.
Course 68, dist., 521; lat. = 195.2, dep. = 483.1.
Course 226, dist., 384; lat. = 266.8, dep. = 276.2.

When the given distances or course angles, which are really the "pairs of arguments" (p. 11) of the traverse table, contain fractions, interpolation can be used; but such close accuracy is seldom, if ever, required in navigation.

More extended traverse tables will be found in Bowditch's "American Practical Navigator," published by the Navy Department, Washington. They are also printed separately in Bowditch's "Useful Tables." Both volumes can be purchased at any "navigation shop" where instruments and books suitable for navigators are sold.

To complete this explanation of our traverse table, it is still necessary to mention that it also provides, with sufficiently close approximation, for the method of measuring

course angles in "points of the compass" (pp. 10, 41). This method is not now in use in the United States Navy, but it is still largely employed in merchant vessels. It is sufficient to state here that a course of 3 points, for instance, is very nearly equal to a course of 34°, and the traverse table column for 34° may properly be used for a 3-point course. Similarly, 31° may be used for $2\frac{3}{4}$ points, and the mariner desiring to use points can always find from the traverse table itself just what column to use. A special traverse table for points may also be found in Bowditch's Tables, already mentioned.

We have now shown how to find latitude difference and departure by means of the traverse table. But our problem is not yet completely solved. Our ship (p. 8) started from the point Y in lat. 42° 11′ N.; long. 59° 28′ W. She traveled 63 miles on a 40° course, and the traverse table showed that she thus made good a latitude difference of 48.3 miles and a departure of 40.5 miles. It now remains to ascertain how much the ship changed her latitude in degrees and minutes from 42° 11′ N. and her longitude in degrees and minutes from 59° 28′ W. When we have found these last changes, we can learn the latitude and longitude of the point P, which we are required to find.

To get the latitude change in degrees and minutes from the latitude difference in miles offers no difficulty. If the miles used are nautical miles (and in navigation they always are nautical miles), each mile of latitude difference corresponds to 1′ of angular measure (p. 9), and 60 miles correspond to 1°. Thus our ship must have changed her latitude 48′.3, corresponding to a latitude difference of 48.3 miles. Her initial latitude having been 42° 11′ N., her final latitude at P will be 42° 11′ + 48′ (if we omit the odd .3) or 42° 59′ N.

The relation between departure and difference of longitude is not quite so simple. Our ship's departure of 40.5 miles might correspond to far more than 40.5 minutes of longitude. In fact, in very high latitudes near the north pole, the longitude meridians converge so closely that a person traveling

a few miles might change his longitude very greatly. At the pole itself a man might change his longitude 180° by simply stepping across the pole. So it follows that the longitude difference in minutes is *greater* than the departure in miles (however, cf. p. 4). The difference between the two increases rapidly as we approach high latitudes though it is *nil* at the equator; in Table 2 (beginning p. 168) we give this excess of longitude difference over departure for all latitudes under 60°, and for all longitude differences up to 100. When the longitude differences are greater than 100, it is necessary to use the numbers given for 100, 200, 300, etc., near the bottom of each page in the table, and to sum tabular numbers, precisely as we did with the traverse table.

It will be noticed that Table 2 gives "tabular numbers" for each degree of latitude in a separate column, and that these various latitudes are called "middle latitudes." Thus the middle latitude and the longitude difference are the pair of arguments (p. 11) for Table 2, and, as we shall see presently, the use of the middle latitude avoids any uncertainty in choosing the correct column for use. In our present problem we have at our disposal (p. 15) two different latitudes: the initial latitude at the point Y, 42° 11′ N., and the final latitude at the point P, 42° 59′ N. In this case, the two latitudes are so nearly equal that we might use either of them as an argument in Table 2 without material inaccuracy. In fact, in using Table 2 it is unnecessary to consider minutes of latitude, the nearest degree being sufficient.

But often the two latitudes available at this stage of the problem differ by many degrees. In such cases mariners always use the average of the two latitudes, and call it the "middle latitude." In the present case, the middle latitude would be found thus:

$$
\begin{aligned}
\text{Initial latitude} &= 42^\circ\ 11' \\
\text{Final latitude} &= \underline{42^\circ\ 59'} \\
\text{Sum} &= 85^\circ\ 10' \\
\tfrac{1}{2}\ \text{sum} = \text{middle latitude} &= 42^\circ\ 35'
\end{aligned}
$$

The nearest even degree to 42° 35′ is 43°, and the problem would therefore be worked with the 43° column of middle latitude in Table 2.

Before completing our problem it is necessary to point out that while Table 2 is intended primarily for changing longitude differences in minutes into departures in miles, it can also be used (as stated at the foot of each page) for the inverse transformation of departures into longitude differences; and this is the transformation we must make in our present problem. It is merely necessary to use the departure (40.5) in the left-hand column, at the head of which are the words "Long. Diff. or Dep.," indicating that either of these two may be used as the argument in that column. Then, in the 43° column of middle latitude, we find (using interpolation) the tabular number 10.8.

This means that a longitude difference of 40′.5 corresponds to a departure of 40.5 − 10.8 miles, or 29.7 miles.

But when the table, as in the present case, is used for the inverse transformation, the tabular number 10.8 must, before use, be multiplied by the factor given at the bottom of the column. For the middle latitude 43° this factor is 1.37; and so the right tabular number becomes, in the present case:

$$10.8 \times 1.37 = 14.8;$$

and as the longitude difference is always greater than the departure, it follows that the departure of 40.5 miles gives a longitude difference of:

$$40.5 + 14.8 = 55'.3 = 0^\circ\ 55',$$

if we omit the odd tenths.

The initial longitude of the ship at the point Y was 59° 28′ W. As her 40° course has carried her nearer to Greenwich, it follows that her final longitude at the point P is:

$$59^\circ\ 28'\ \text{W.} - 0^\circ\ 55' = 58^\circ\ 33'\ \text{W.}$$

We shall now discuss the following similar problem:

A ship takes her departure from a point about one mile

east of Navesink Highlands Light, New Jersey, in the initial lat. 40° 24′ N., initial long. 73° 58′ W., and travels 1377 miles on a course of 166°. What final latitude and longitude does she attain?

Entering the traverse table in the column headed 166°, which is the same as the 14° column, we find:

For dist.	900, lat.,	873.2, dep.,	217.7
For dist.	400, lat.,	388.1, dep.,	96.7
For dist.	77, lat.,	74.7, dep.,	18.6
Sums,	1377,	1336.0,	333.0

To make the large given distance (1377 miles) come within the range of Table 1, it has been necessary to enter the 166° column three times, with the arguments 900, 400, and 77, and then to sum the corresponding tabular numbers.

The latitude difference, 1336 miles, is equivalent to 1336′, or 22° 16′, counting, as usual, 60′ to 1°. Then, since the direction of her course (166°) carried the ship to the south of her initial position (cf. Fig. 5, p. 14, and p. 19), we have:

Initial lat.,	40° 24′ N.
Lat. diff.,	22° 16′ N.
Final lat.,	18° 8′ N.
Middle lat.,	29° 16′ N.

Now turning to Table 2, in the proper column for middle latitude 29°:

For dep.	300 tabular number is	37.6
For dep.	33 tabular number is	4.1
Sums	333	41.7

As in the former example, this 41.7 must be multiplied by the factor at the bottom of the column. This factor is 1.14. Multiplying, we have: $41.7 \times 1.14 = 47.5$. Consequently, long. diff. $= 333 + 47.5 = 380'.5 = 6° 20'.5$. Since the direction of her course (166°) carried the ship eastward, and therefore nearer to Greenwich, it follows that her final longitude is 73° 58′ W. − 6° 20′, or 67° 38′ W. The final position is therefore: lat. 18° 8′ N.; long. 67° 38′ W.

The point indicated by this final latitude and longitude is just off the entrance to the Mona Passage, between Haiti and Porto Rico; the given course and distance would therefore be correct for a voyage from New York to Mona Passage

Additional similar problems are:

1. Initial lat., 40° 28′ N.; initial long., 73° 50′ W.; course, 119°; dist., 2924 miles. This would take the ship from Sandy Hook to St. Vincent, Cape Verde Islands.

Ans. Final lat., 16° 50′ N.; final long., 25° 7′ W.

2. Initial lat., 40° 10′ N.; initial long., 70° 0′ W.; course, 75°; dist., 2606 miles. This would take the ship from Nantucket Lightship to Fastnet, the nearest point of the Irish coast.

Ans. Final lat., 51° 24′ N.; final long., 9° 37′ W.

Before proceeding to our second fundamental problem (p. 8), it will be well to explain briefly two further points of interest. The first of these relates to the method of designating a ship's course. We have hitherto supposed it to be measured in degrees, from the north, around by way of the east, through the south and west, and so back to the north again. This is the best way to count courses, and is the way now in use in the United States Navy. Since a whole circle contains 360°, it follows that courses may contain any number of degrees from 0° to 360°.

But there is another quite convenient, although older, way of designating courses, in which a 60° course, for instance, is written N. 60° E., showing that the ship must be steered 60° east of north. In a similar way, a 120° course is written S. 60° E., showing that the helmsman should head her 60° east of south, which would be the same as 30° south of east, or 120° from the north toward the south by way of east.

The second further point of interest has to do with the relation between Tables 1 and 2. It is possible to avoid entirely the use of Table 2, and to transform longitude differences into departures, and *vice versa*, by means of Table 1

alone. It so happens that the relation between these two, for any given middle latitude, as, for instance, 29°, is identical with the relation between distance and latitude difference in Table 1 for the course 29°. In other words, if we have given a middle latitude and a longitude difference, and wish to find the departure, we:

Call the middle latitude a course, and
Call the longitude difference a distance;

Then, corresponding to that course and distance, find from Table 1 the tabular latitude difference, and it will be the required departure. The same process can also be reversed, so as to find the longitude difference from the departure.

While this method with Table 1 is quite correct, we believe beginners (at least) will find the use of Table 2 advantageous in the solution of these problems, especially when the middle latitude is not very great.

Coming now to our second fundamental problem of dead reckoning, let us suppose a ship is required to proceed from the initial lat. 42° 11′ N. and long. 59° 28′ W. to a final lat. 42° 59′ N. and long. 58° 33′ W. We are to find the course she must steer, and the distance she must run.

We have at once the latitude difference of 0° 48′, or 48 miles, and the middle latitude 42° 35′, or nearest whole degree of middle latitude, 43°. The longitude difference is 55′; and with this we find from Table 2 the correction 14.8 in the 43° column of middle latitude. Remembering that this time we are transforming a longitude difference into departure, and consequently do not need to use the factor at the foot of the column, we subtract this correction (14.8) from the longitude difference (55′) and obtain the departure as 40.2 miles.

Next we proceed to Table 1, to find the course and distance corresponding to lat. 48, dep. 40.2. To do this, we must find a place in Table 1 where this particular latitude and departure appear side by side. If this pair of numbers

cannot be found (exactly) side by side, we must take the pair which come nearest to them: in this case such a pair of numbers is found in the 40° course column, opposite dist. 63. So it appears that the ship must steer on a 40° course a distance of 63 miles, to proceed from the given initial to the given final latitude and longitude. This problem is the direct converse of the one first solved (pp. 15, 17).

As a second example, let us now calculate the course and distance from Sandy Hook, lat. 40° 28′ N.; long. 73° 50′ W., to St. Vincent, lat. 16° 50′ N.; long. 25° 7′ W. We have, by subtraction, lat. diff. = 23° 38′ = 1418′ = 1418 miles; long. diff. = 48° 43′ = 2923′.

This 2923′ must be turned into a departure, the middle latitude being 28° 39′, or, to the nearest whole degree, 29°. Turning to the column of Table 2 which belongs to 29° of middle latitude, we find the correction for 2923′ of longitude difference thus:

Tabular number for	900 = 113.0,

which being multiplied by 3, gives:

Tabular number for	2700 =	339.0
Also, tabular number for	200 =	25.1
Tabular number for	23 =	2.9
Sums, tabular number for	2923 =	367.0

This must be subtracted from the longitude difference, and so we get:

$$\text{dep.} = 2923 - 367.0 = 2556 \text{ miles.}$$

We have now to seek a place in Table 1 where lat. 1418 and dep. 2556 appear side by side. No traverse tables are sufficiently extended to contain these large numbers, but we can at once obtain an approximate answer to the problem by dividing both numbers by 100. This reduces them to lat. 14.2, dep. 25.6; and the nearest numbers to these which can be found side by side in Table 1 are in the column belonging to course 119° and opposite dist. 29. This course (119°) is the same as would have been obtained if we had not been

forced to divide our latitude and departure by 100, to bring them within the range of Table 1. But the dist. 29 must now be multiplied by 100, to remove the effect of our former division of latitude and departure by 100. Thus we have the closely approximate information that the course and distance from Sandy Hook to St. Vincent are 119° and 2900 miles. The same problem (p. 19), when taken in its inverse form, starts with the numbers 119° and 2924 miles.

In discussing such a problem, many beginners have difficulty in choosing correctly the course number (119°) from the four (61°, 119°, 241°, 299°) to be found at the foot of the same column of Table 1. This choice is easily made with the help of our knowledge of elementary geography, or with any rough chart or map. From these, we know that St. Vincent is south and east of Sandy Hook, and the only one of the four possible courses that will carry a ship south and east is course 119°. The same course might be written in the other notation (p. 19) S. 61° E., which possibly makes the actual direction to be steered a little easier to understand.

The above result is approximate only, but higher accuracy is seldom required. When desired, it can be obtained by certain kinds of interpolations (p. 12); but these are always unsatisfactory, especially as complete precision can always be easily had by the use of logarithms, as explained in the next chapter.

CHAPTER III

DEAD RECKONING WITH LOGARITHMS

SINCE the publication in 1876 of Kelvin's tables for facilitating Sumner's method, it has been possible to navigate in the most approved way without using logarithms or trigonometry. Those who desire to study the subject in this manner may do so by simply omitting those parts of the book in which logarithmic or trigonometric formulas and calculations occur. But this method of study is not recommended, except perhaps for a first reading; for a knowledge of logarithmic processes always affords a most desirable check on the accuracy of the other method, and so makes for safety of the ship and peace of mind of the navigator.

Proceeding, then, with the subject of logarithms, we may define them as a mathematical device for facilitating calculations. They are merely numbers; but they are numbers having this peculiarity: every logarithmic number belongs to some ordinary number (like 1, 2, 3, 27, 800, etc.), and belongs to it alone. Its logarithm belongs to the number as a man's shadow belongs to the man.

For our present purpose it is unnecessary to enter into the theory of logarithms; we shall explain only the methods of using them in practice. Logarithms (abbreviated "log") always consist of two parts, a "whole number" part and a "decimal" part. Thus, 3.30103 is a logarithm, of which the whole number part is 3, and the decimal part .30103. The whole number part may even be zero: thus, 0.30103 is also a logarithm. The decimal part of the logarithm is found from a table of logarithms, such as our Table 3

(p. 178); but the whole number part is found by an inspection of the number to which the logarithm belongs.

We shall hereafter, to save space, always write "log 26" in place of "the logarithm belonging to 26": and, with the help of this abbreviation, we may now write the following tabular statement, which is fundamental in the matter of logarithms:

$$\begin{array}{ll} \log 1 \;\;\;\;\, = 0.00000, & \log 1000 \;\;\;\, = 3.00000, \\ \log 10 \;\;\, = 1.00000, & \log 10000 \;\, = 4.00000, \\ \log 100 = 2.00000, & \log 100000 = 5.00000, \text{ etc.} \end{array}$$

In other words, for these particular numbers, all "multiples" of 10, the decimal part of the log is zero. For numbers intermediate between 1 and 10, the whole number part of the log is 0, and the decimal part lies between .00000 and .99999. For those between 10 and 100 the whole number part is 1, and the decimal part again lies between .00000 and .99999.

The general rule is: the whole number part of a log is one *less* than the number of figures or "digits" in the number to which the log belongs. Thus, the number 26 has two digits: the whole number part of its log is 1. The number 2678 has four digits: the whole number part of its log is therefore 3.

If a number is itself partly decimal, we count only the number of digits to the left of the decimal point for the purposes of the present rule. Thus, 26.78 has two digits only; 2.678 has one; 267.8 has three, etc.

If, on the other hand, a number is wholly decimal, as 0.2678, the whole number part of its logarithm should be "negative," or *minus*, *i.e.* less than 0; and it will be one *greater* than the number of zeros immediately following the decimal point in the number. According to this, the whole number part of log 0.2678 should be -1, because this number has *no* zeros immediately following the decimal point. But as these negative whole number parts are very inconvenient in actual work, it is customary to increase

all logs of decimal numbers arbitrarily by 10, which will avoid the negative sign. This arbitrary increase is always corrected again in the further or final procedure, so that it cannot possibly introduce error into the work.

In the case of log 0.2678, the arbitrary increase of 10 changes the -1 to $+9$[1]; and so 9 would be the whole number part of log 0.2678. Similarly, log 0.002678 would have 7 for its whole number part, because there are two zeros after the decimal point. This would make the whole number part of the log -3, which, being increased by 10, gives $+7$.

In general, this matter of logs of wholly decimal numbers may be summarized as follows:

$$\begin{array}{ll} \log 0.1 = 9.00000, & \log 0.0001 = 6.00000, \\ \log 0.01 = 8.00000, & \log 0.00001 = 5.00000, \\ \log 0.001 = 7.00000, & \log 0.000001 = 4.00000, \text{ etc.} \end{array}$$

In all these cases the decimal part of the log is zero: and if the number lies, for instance, between 0.1 and 0.01, the whole number part of the log will be 8, and the decimal part will lie between .00000 and .99999.

The decimal part in the log of any number is taken from Table 3 without regard to the position of the decimal point in the number itself. The numbers 0.2678, 0.002678, 26.78, 2.678, 267.8, and 2678 all have precisely the same decimal part in their logs, so that such logs will differ in their whole number parts only. We can at once obtain this common decimal part from Table 3 (p. 181), where it is found to be .42781. In looking up this log, we again use (p. 11) a pair of arguments. The argument for the left-hand column consists of the first three digits of 2678 (267); and in selecting this argument we disregard any zeros that may immediately follow the decimal point, if the number is wholly decimal, like .002678. The other argument, in the top horizontal line of the tabular page is 8, the right-hand digit of the number 2678. In the horizontal line

[1] According to Algebra, 9 is greater than -1 by 10.

opposite 267, and in the column headed 8, appears 781; and these are the last three digits of the required log (.42781). The first two digits (.42) are common to a great many logs, and are therefore only printed in the column headed 0. The first two digits of every log are thus taken from the zero column, regularly from the same horizontal line that contains the last three digits of the log, or from some line above it. Only when there is an asterisk printed in the table with the last three digits do we make an exception, and take the first two digits from the line *below* the one containing the last three. Thus the decimal part of log 2691 is .42991, but the decimal part of log 2692 is .43008.

Having thus found the decimal part of log 2678 to be .42781, and the number 2678 having four digits, the complete

$$\log 2678 = 3.42781;$$

and here the reader should once more note that all tabular logs like .42781 are thus always decimals. The corresponding logs for the other numbers given above are:

$$\begin{aligned} \log\ 267.8 &= 2.42781, \\ \log\ 26.78 &= 1.42781, \\ \log\ 2.678 &= 0.42781, \\ \log\ 0.2678 &= 9.42781, \\ \log 0.002678 &= 7.42781. \end{aligned}$$

It is clear that Table 3 gives directly the decimal part of the logs of all numbers containing four digits. If the number contains less than four digits, as 26, we should look it up in the table as if it were 2600. We should find 260 as the argument in the left-hand column (p. 181); and in the corresponding line, in the column headed 0 (the fourth digit of 2600), is 41497. This is the decimal part, as usual, and the complete

$$\log 26 = 1.41497.$$

If, on the other hand, the number whose log is wanted contains more than four digits, as 26782, it is necessary to

resort to interpolation (p. 12). The number of digits being here 5, the whole number part of the log is 4 (p. 24). The decimal part of the log is to be found quite without regard to decimal points (p. 25). It may therefore be taken from Table 3 just as if we wanted log 2678.2 instead of 26782. Now the table tells us (p. 181):

$$\text{decimal part of log } 2678 = 42781,$$
$$\text{decimal part of log } 2679 = 42797.$$

The tabular difference (p. 12) of these two decimal parts is 16. As 26782 may, for our present purpose, be regarded as lying $\frac{2}{10}$ of the way from 2678 to 2679, it follows that the decimal part of log 26782 will lie $\frac{2}{10}$ of the way from 42781 to 42797. Evidently, we must multiply the tabular difference 16 by $\frac{2}{10}$ (giving 3.2) to find how much larger the decimal part of log 26782 is than the decimal part of log 2678. This 3.2 (or 3, in round numbers) must then be added to 42781; and we have, as the result of this interpolation:

$$\text{decimal part of log } 26782 = .42784.$$

As we have just found the whole number part to be 4, we have for the complete:

$$\log 26782 = 4.42784.$$

This whole process of interpolation may perhaps be more clearly understood if we repeat (p. 10) that all tables furnish tabular numbers corresponding to given arguments. Interpolation is necessary when the given arguments are not to be found in the argument part of the table, but fall between two of the tabular arguments. Then we obtain by subtraction the difference between the given argument and the nearest smaller argument contained in the table. This difference is the "argument difference" (abbreviated, arg. diff.), and it should be expressed as a decimal fraction of the interval between two successive arguments (cf. $\frac{2}{10}$, above). The tabular difference (tab. diff.) between two successive tabular numbers being also obtained by subtrac-

tion, we have only to multiply the tabular difference by the argument difference to find the "interpolation difference" (int. diff.). This is then added[1] to the proper tabular number (belonging to the above-mentioned nearest argument given in the table) to obtain the tabular number required.

The multiplication of the tabular difference by the argument difference is facilitated by certain little auxiliary multiplication tables (called tables of "proportional parts") printed in the margins of many mathematical tables. In the example given above, the tabular difference was 16; and Table 3 contains on the proper page (p. 181) a proportional part table headed with this same number 16; and it shows that for an argument difference .2, and tabular difference 16, the interpolation difference is 3.2, just as we found above.

Other examples of logarithms are:

$$\begin{aligned}
&\log 427 = 2.63043, &&\log 42765 = 4.63109,\\
&\log 4276 = 3.63104, &&\log 282374 = 5.45082,\\
&\log 0.4276 = 9.63104, &&\log 2 = 0.30103,\\
&\log 0.42765 = 9.63109, &&\log .0027 = 7.43136.
\end{aligned}$$

The above considerations are preparatory only to the actual use of Table 3; and they are not yet quite complete. For it is still necessary to explain the inverse use (p. 12) of the table, or, in other words, the finding of the number to which a given log belongs. Thus, if the given log were 3.42781, we should begin by looking up its decimal part among the logs in the table. Finding it there, we take out the number to which it belongs, 2678. We then put in the decimal point according to the whole number part of the log. This being 3, we know (p. 24) that the number required must contain 4 digits. Therefore:

number to which the log 3.42781 belongs = 2678.

[1] Except when a glance at the table shows that the tabular numbers are growing smaller, in which case the interpolation difference must be subtracted. This never occurs in Table 3, but happens frequently in Table 4.

If the given log had been 2.42781, the table would furnish the same number 2678, but the decimal point would be differently located. Because the whole number part of the given log is now 2, we know that the number to which it belongs has three digits, and so:

number to which the log 2.42781 belongs = 267.8.

When the given log is not to be found in the table exactly, a process of inverse interpolation is, of course, necessary. Thus, if the given log is 4.42784, we look for its decimal part in the table, and find it lies between

42781, which belongs to the number 2678, and
42797, which belongs to the number 2679.

The decimal part of the given log being 42784 is greater by 3 than the nearest tabular number 42781. This 3 is therefore the interpolation difference. The tabular difference is 16, obtained by subtraction between 42781 and 42797. We now divide the interpolation difference by the tabular difference, which gives .2 ($\frac{3}{16}$ = 0.2, in round numbers). This .2 is the argument difference, and therefore the complete number belonging to the decimal part of the log (42784) is 26782. The whole number part of the given log being 4, the required number must have 5 digits, and will therefore be 26782. Had the given log been 2.42784, we should have arrived at the number 26782 in just the same way; but we should locate the decimal point differently. The whole number part of the log being now 2, there should be only 3 digits in the number, and we should have:

number to which the log 2.42784 belongs = 267.82.

Other similar examples are:

log = 2.71828, corresponding number = 522.73,
log = 4.26323, corresponding number = 18333,
log = 9.26323, corresponding number = 0.18333,
log = 0.21000, corresponding number = 1.6218.

The reader will perceive, from a consideration of these interpolated numbers, that work with logarithms is never

exact, *absolutely*. This is inherent in the nature of our log tables, which really contain only the decimal parts of the logs carried out to five places of decimals. Further decimals of course exist, but are here omitted, because five places always give sufficient accuracy for navigation calculations.

The simplest calculations which are facilitated by logarithms are the ordinary arithmetical processes of multiplication and division. These processes can be turned into addition and subtraction by the use of the following principle:

The log of a product is equal to the sum of the logs of the factors.

According to this principle, if we wish to multiply a series of factors, we simply add their logs. The sum is then a log and the number to which this log belongs is the product of the series of factors. Suppose, for instance, we wish to multiply the factors 2, 3, and 4. The product should be 24. Proceeding with logs, we have from Table 3:

$$\begin{aligned} \log 2 &= 0.30103, \\ \log 3 &= 0.47712, \\ \log 4 &= \underline{0.60206,} \\ \log \text{product} = \text{sum} &= 1.38021, \end{aligned}$$

and the number to which the log. 1.38021 belongs is, according to Table 3, 24.00, the correct product.

It is evident that the use of the log table is here of no advantage, because the factors are very small: but when large numbers are to be multiplied the advantage is very great.

Taking now a similar simple example of division, let us divide 6 by 3. In division, evidently, we must subtract the log of the divisor from the log of the dividend, to obtain the log of the quotient. We have

$$\begin{aligned} \log 6 &= 0.77815, \\ \log 3 &= \underline{0.47712,} \\ \log \tfrac{6}{3} = \text{difference} &= 0.30103, \end{aligned}$$

and the number to which the log 0.30103 belongs is 2.000, the correct quotient. Other examples are:

$$2.426 \times 42.78 \times 17.26 = 1791.3,$$
$$6.242 \times 87.24 \times 62.71 = 34149,$$
$$\frac{2802}{1726} = 1.6234,$$
$$\frac{18}{24} = 0.75.$$

In the last example, we have

$$\log 18 = 1.25527,$$
$$\log 24 = 1.38021.$$

The subtraction would lead to a negative log because 1.38021 is larger than 1.25527. Therefore we arbitrarily increase 1.25527 by 10, giving 11.25527, and then the subtraction gives

$$\log \text{quotient} = 9.87506,$$

which is the log belonging to the number 0.75, the correct quotient.

We come now to the solution of the two fundamental problems of dead reckoning (pp. 8, 10) by means of logs. For this purpose we must use our Table 4, in connection with Table 3. Table 4 is called a trigonometric log table and the tabular numbers in it are certain logs known as:

sine,	abbreviated sin,	cotangent,	abbreviated cot,
cosine,	abbreviated cos,	secant,	abbreviated sec,
tangent,	abbreviated tan,	cosecant,	abbreviated csc.

It is not our purpose to consider the theory of trigonometry, but it is necessary for the reader to have some understanding of its practical applications. If we have a triangle *QPY* (fig. 6), we notice that it is made up of six "parts," the three sides and the three angles. Now it is a fact that if we know any three of these six parts, we can calculate the other three parts, provided one of the known parts is a side. Trigonometry is the branch of mathematics which enables us

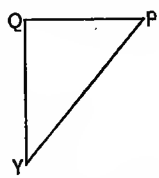

Fig. 6. — Trigonometry.

to do this, and the triangle QPY is the very triangle which occurs in the two problems of dead reckoning.

In trigonometry, every angle has belonging to it a sin, cos, etc., just as every number has its log. These sines, etc., can be taken out of Table 4 by means of a pair of arguments in the usual way. The two arguments are the number of degrees and the number of minutes in the angle (p. 9). The number of degrees is found in Table 4 at the top or bottom of the page, and the number of minutes in the right-hand or left-hand column. Each page (as, for instance, p. 229) has eight degree numbers, four, 33°, (213°), (326°), and 146° at the top, and four, 123°, (303°), (236°), and 56° at the bottom. The proper sines, etc., for all these degrees appear on the same page (p. 229). When the degree number is at the top or bottom of the left-hand column 33°, (213°), (303°), and 123°, the minutes must be taken from the left-hand column. But when the number of degrees is at the top or bottom of the right-hand column 146°, (326°), (236°), and 56°, the minutes must come from the right-hand column. And when the number of degrees comes from the top of the page, we must look for the proper sine, etc., in a column having the word sin, etc., at the top. But when the degree number comes from the bottom of the page, the sine, etc., will be taken from a column having the word sin, etc., at the bottom. Thus (p. 229):

$$\sin 33^\circ\, 26' = \sin 146^\circ\, 34' = \cos 56^\circ\, 34' = \cos 123^\circ\, 26' = 9.74113.$$

In this way, sines, tangents, etc., can be taken from Table 4. Examples are:

$$\begin{aligned} &\sin\ 28^\circ\, 32' = 9.67913, && \cot 117^\circ\, 10' = 9.71028,\\ &\cos\ 66^\circ\, 14' = 9.60532, && \sec\ 12^\circ\, 40' = 0.01070,\\ &\tan 128^\circ\, 28' = 0.09991, && \csc 111^\circ\, 11' = 0.03038. \end{aligned}$$

These sines, etc., are really all logs. When the whole number part is 9, it indicates that the log belongs to a number which is wholly decimal (see p. 24), and that the log has been arbitrarily increased by 10.

Of course these trigonometric tables can also be used in the inverse manner. Thus, to find the angle corresponding to the sin 9.28190, we turn to p. 207, and finding 9.28190 in the sin column, we see that the corresponding angle is either 11° 2′, 191° 2′, 168° 58′, or 348° 58′. When the sin, etc., cannot be found in the table exactly, we may always take the nearest one: interpolation is never practically necessary in using the trigonometric tables in navigation. Examples are:

sec = 0.17177, angle = 47° 40′, 227° 40′, 132° 20′, or 312° 20′,
tan = 0.17177, angle = 56° 3′, 236° 3′, 123° 57′, or 303° 57′,
sin = 9.17177, angle = 8° 32′, 188° 32′, 171° 28′, or 351° 28′,
cos = 9.17177, angle = 81° 28′, 261° 28′, 98° 32′, or 278° 32′,
csc = 0.17177, angle = 42° 20′, 222° 20′, 137° 40′, or 317° 40′,
cot = 0.17177, angle = 33° 57′, 213° 57′, 146° 3′, or 326° 3′.

Having thus explained the use of Table 4, we shall now apply it to the two problems of dead reckoning. These problems are:

1. To find latitude difference and departure from course and distance;

2. To find course and distance from latitude difference and departure.

These problems are solved by means of the following formulas, in which the letter C represents the course angle:

$$(1)\quad \begin{cases} \text{log lat. diff.} = \text{log dist.} + \cos C, \\ \text{log dep.} = \text{log dist.} + \sin C. \end{cases}$$

$$(2)\quad \begin{cases} \tan C = \text{log dep.} - \text{log lat. diff.}, \\ \text{log dist.} = \text{log dep.} - \sin C. \end{cases}$$

Sometimes it is preferable to find the distance from the latitude difference instead of the departure. We then use the following modification of formula (2):

$$(2')\quad \text{log dist.} = \text{log lat. diff.} - \cos C.$$

Let us now solve with these formulas our former problem (p. 18), in which a ship traveled 1377 miles on a course of 166°. Applying formula (1) above, we have:

log dist. (1377)	= 3.13893	log dist. (1377)	= 3.13893
cos C (166°)	= 9.98690	sin C (166°)	= 9.38368
sum = log lat. diff.	= 3.12583[1]	sum = log dep.	= 2.52261[1]
corresponding lat. diff.	= 1336.1	corresponding dep.	= 333.1

These corresponding latitude difference and departure agree very closely with the results already found (p. 18) from Table 1.

If the departure and latitude difference were given, we could find the course and distance by means of formula (2). In the present case we have:

log dep. (333.1)	= 2.52261	log dep. (333.1)	= 2.52261
log lat. diff. (1336.1)	= 3.12583	sin C (166°)	= 9.38368
by subtraction, tan C	= 9.39678[2]	by subtraction, log dist.	= 3.13893[3]
corresponding C	= 166°	corresponding dist.	= 1377

These numbers, 166° and 1377 miles, are the same numbers with which we began this calculation; so it is clear that the log method of calculation agrees with the traverse table method. For accuracy the log method is superior.

The transformations of departure into longitude difference, and *vice versa*, are accomplished logarithmically with the following formulas:

(3) log long. diff. = log dep. − cos middle lat.
(4) log dep. = log long. diff. + cos middle lat.

Thus the longitude difference corresponding to dep. 333.1 would be calculated by formula (3) as follows:

log dep. (333.1)	= 2.52261
cos mid. lat. (29° 16′, p. 18)	= 9.94069
by subtraction, log long. diff.	= 2.58192
corresponding long. diff.	= 381′.9 = 6° 21′.9.

[1] These numbers have been diminished by 10, to allow for the fact that both cos C and sin C have been arbitrarily increased by 10 (p. 32; cf. also p. 25).

[2] This number has been increased by 10, and therefore is in accord with the usual practice of avoiding negative whole numbers in the trigonometric Table 4.

[3] This subtraction is correct, if we remember that the 9.38368 is really too large by 10.

This is in close accord with the result on p. 18, where Table 2 gave 6° 20′.5. The logarithmic method is again the more precise, for it takes account of minutes in the course, which were neglected on p. 18. But either result is accurate enough for practical purposes.

Before finally leaving these problems of dead reckoning, we shall explain briefly two additional methods of solving them which differ from the method so far employed. These two additional methods are called "Mercator sailing" and "great circle sailing"; whereas, up to the present, we have been using "middle latitude sailing," so named because the middle latitude appears in the calculations.

Mercator sailing is based on a kind of chart first designed by Gerhard Mercator, a sixteenth century geographer. Such charts are still widely used for nautical purposes. In calculations based on them, every parallel of latitude is referred directly to the equator by means of a table of "meridional parts." Our Table 5 is such a table, and it gives the meridional part for every degree and minute of latitude from the equator to 60°. These meridional parts are really the distances from the equator to the several parallels of latitude, such as they would appear on a Mercator chart drawn to such a scale that 1′ of longitude at the equator would occupy one linear unit on the chart. Thus the meridional part for lat. 40° is given in Table 5 as 2607.6. Suppose the scale of the chart at the equator were 1 inch to the degree of longitude. That would be $\frac{1}{60}$ inch to the minute. The distance on the chart from the equator to the 40° parallel of latitude would then be $2607.6 \times \frac{1}{60}$ inches = 43.46 inches. It is needless to say that a chart on such a scale could not show a very large part of the ocean on a single sheet.

Calculations by Mercator sailing are of course only made when the distances involved are large and great accuracy is required. It is therefore best to do them by means of logarithms, although it is also possible to obtain Mercator results from the traverse table. In such calculations we do not

use the latitude difference of ordinary middle latitude sailing. In its place appears the "meridional latitude difference" (abbreviated mer. lat. diff.), defined as the difference between the meridional parts (Table 5) belonging to the two latitudes (initial and final) involved in the problem. With this definition in mind we may now give the Mercator formulas as follows:

(5) log mer. lat. diff. = log long. diff. + cot C.
(6) log long. diff. = log mer. lat. diff. + tan C.
(7) tan C = log long. diff. − log mer. lat. diff.

Let us now apply these formulas to the problem of pp. 18 and 33, in which a ship starts from the initial lat. 40° 24′ N.; long. 73° 58′ W., and travels 1377 miles on a course, C, of 166°. What final latitude and longitude does she attain? The latitude difference is found in the ordinary way (p. 34), there being no special Mercator formula for it, and comes out 1336.1 miles, or 1336′.1 = 22° 16′. The final latitude (p. 18) is therefore 40° 24′ − 22° 16′ = 18° 8′. Then, from Table 5, we have:

for initial lat. 40° 24′, mer. parts	= 2638.9
for final lat. 18° 8′, mer. parts	= 1099.4
by subtraction,[1] mer. lat. diff.	= 1539.5

Now, applying formula (6), we have:

log mer. lat. diff. (1539.5) (Table 3, p. 179)	= 3.18738
tan C (166°) (Table 4, p. 209)	= 9.39677
by addition, log long. diff.	= 2.58415
corresponding long. diff. (Table 3, p. 183)	≐ 383′.8 = 6° 24′

The final longitude is therefore 73° 58′ − 6° 24′ = 67° 34′ W., whereas we obtained before 67° 38′ W. (p. 18).

Finally, we shall apply the Mercator method to the example of p. 21. It is required to find the course and distance from

Sandy Hook, lat. 40° 28′ N.; long. 73° 50′ W. to
St. Vincent, lat. 16° 50′ N.; long. 25° 7′ W.

[1] If one latitude were in the southern hemisphere and the other in the northern, we should add the meridional parts.

We have from Table 5:

for initial lat. 40° 28′, mer. parts	= 2644.2
for final lat. 16° 50′, mer. parts	= 1018.1
by subtraction, mer. lat. diff.	= 1626.1

The longitude difference is found by subtraction to be 73° 50′ − 25° 7′ = 48° 43′ = 2923′. Now applying formula (7), we have:

log long. diff. (2923) (Table 3)	= 3.46583
log mer. lat. diff. (1626) (Table 3)	= 3.21112
by subtraction, tan C	= 0.25471

and therefore (Table 4) C = 119° 5′.

The distance is found in the ordinary way from the latitude difference (*not* mer. lat. diff.) by means of formula (2′), p. 33.

The latitude difference is 40° 28′ − 16° 50′ = 23° 38′ = 1418′. Formula (2′) then gives:

log lat. diff. (1418′) (Table 3)	= 3.15168
cos C (119° 5′) (Table 4)	= 9.68671[1]
by subtraction, log dist.	= 3.46497[1]
corresponding dist. (Table 3)	= 2917

Course 119° 5′, distance 2917 miles is therefore the solution by Mercator sailing. On p. 22, we obtained 119° and 2900 miles; and on p. 19 we began with 119° and 2924 miles. The agreement is satisfactory.

Having thus briefly described Mercator sailing, we come next to "great circle sailing." This is a method of determining the ship's course toward her port of destination in such a way that the distance to be traveled will be as short as possible. If the earth's surface were flat instead of spherical, the shortest course would be a straight line, as used in plane sailing; but on the sphere the shortest course is a curve called a "great circle." Evidently, on all long voyages, the great circle course is the most advantageous one; that mariners do not more frequently use it is due to a peculiarity of their charts.

[1] This log is really too large by 10, so the subtraction is correct.

We cannot here enter into the details of chart "projections," as the theory of chart making is called. It is sufficient to remark that a straight line drawn on the ordinary nautical charts (which follow the Mercator system), between any two ports, will not represent the shortest (or great circle) course between them. On such a chart, the great circle course between the two ports will *appear* to be longer than the straight line course, although it is really shorter. This accounts for the use of the longer Mercator course by many navigators.

Now there is a kind of chart, called a "great circle sailing" chart, on which straight lines between ports really represent shortest (or great circle) courses. One would therefore naturally suppose that mariners would entirely discontinue the use of Mercator charts in favor of great circle charts. But there is a reason for not doing this.

On Mercator charts, all terrestrial longitude meridians are represented by parallel vertical straight lines. Consequently, if we draw another straight line on the Mercator chart joining two ports, that line will make the same course angle (p. 10) with all the meridians. In this way, a navigator can get from a Mercator chart, by simply drawing a straight line, and quite without calculation, a course angle which will carry him from one port to another. And because the course angle so obtained is the same with respect to all meridians to be crossed by the ship it follows that the voyage can be completed (theoretically at least) from the one port to the other with the great advantage of never changing the course to be steered.

On the other hand, the great circle track makes a different angle with every meridian it passes: so that the mariner must make very frequent changes in the course angle to be steered during the progress of a voyage. The simple Mercator track, without change of course, is called a "rhumb line"; the serious objection to it is that it sometimes leads to greatly (and unnecessarily) lengthened voyages.

The final conclusion is that Mercator charts, on account of their simplicity, are most convenient for short voyages, or for parts of long voyages when the land is not far away. But for shaping the main part of the course on a very long voyage, great circle sailing charts are to be preferred.

At times, in order to avoid very high latitudes, or to round some projecting point of land, navigators must substitute for a single great circle track one "composed" of two or more shorter arcs of great circles. This is called "composite" sailing.

Finally, for the sake of completeness, we shall merely mention two other kinds of sailing. "Parallel" sailing, which is simply middle latitude sailing when the latitude difference is zero; and "traverse" sailing, from which the traverse table gets its name. This is also the same thing as middle latitude sailing; but the special word "traverse" is used when the ship changes her course frequently, perhaps even during a single day. It is then possible to sum up the result of all the short courses which together make up the day's run. It is merely necessary to take from the traverse table the latitude difference and departure for each short course separately, and then to add[1] all the values of latitude difference for a "summed latitude difference," and all the values of departure for a "summed departure." With these a "composite course and distance" can be taken from the traverse table, or calculated with logs, and these will represent the motion of the ship, just as if she had steered an unchanged course during the entire day.

[1] It is necessary to sum separately latitude differences representing northward motion of the ship and those representing southward motion. The *difference* of the two sums is what we need to know. The same is true of departures representing eastward and westward motion of the ship.

CHAPTER IV

THE COMPASS

THE ship's course has been defined (p. 8) as the angle between the north and the direction in which the ship is sailing. To ascertain what this angle is, or, in other words, to steer the ship, mariners use the compass. The dial (or "card") of this instrument is divided, like any circle, into 360°. In the United States Navy these are numbered in such a way (fig. 7) that 0° appears at the north, 90° at the east, 180° at the south, and 270° at the west. The numbers therefore increase in a "clockwise" direction. There are also compasses in which the numbering begins with 0° at both the north and south points, and increases to 90° at the east and west points. But the United States Navy system of numbering is to be preferred.

In addition to the above division and numbering, the dial is also divided into 32 points (pp. 10, 15), each containing $\frac{360°}{32}$, or $11\frac{1}{4}°$. These points are then further subdivided into quarter points, all of which is shown clearly in Fig. 7.

The naming of the points has not been done by chance, but in accordance with a definite rule. The four principal, or "cardinal," points are north, east, south, and west. The remaining points are located by a continued process of halving. Halfway between the cardinal points are the "inter-cardinal" points; and each is named by combining the names of the two cardinal points adjacent to it. Thus northeast (abbreviated N.E.) is halfway between north and east. Again halving and combining names, we get points like E.N.E., S.S.E., etc. Still once more halving completes the tally of 32 points: but a combination of names would now be too complicated. However, since

each of these final points must necessarily be adjacent to a cardinal or inter-cardinal point, they are named by simply increasing the name of such adjacent cardinal or inter-cardinal point. This is accomplished with the word "by."

FIG. 7. — Compass Card.

Thus we find, adjacent to N.E., the points N.E. by E., and N.E. by N. In the light of the above, it is easy to "box" the compass, as seamen say, or to name the 32 points in order.

When the point system of division is used, and an accuracy

closer than a single point is required, the compass card is still further subdivided into quarter points. In naming these it is customary, in the United States Navy, to "box" from N. and S. towards E. and W. Thus the space between N.N.E. and N.E. by N. would be divided into four parts thus: N.N.E.$\frac{1}{4}$E., N.N.E.$\frac{1}{2}$E., N.N.E.$\frac{3}{4}$E. But an exception is made to this last rule in the case of quarter points adjacent to a cardinal or inter-cardinal point. These last are always put first in naming the quarter points. Thus, between E. by N. and E., if we *always* boxed from N. towards E., we should have: E. by N.$\frac{1}{4}$E., E. by N.$\frac{1}{2}$E., E. by N.$\frac{3}{4}$E. But it is customary, because shorter, to name these quarter points E.$\frac{3}{4}$N., E.$\frac{1}{2}$N., and E.$\frac{1}{4}$N.

Inside the "bowl" of the compass, and adjacent to the card, a black line is marked on the bowl. This line is in plain view of the steersman, through the glass cover of the compass, and is called the "lubber line." When the ship is headed in such a way that this line comes opposite N.E., for instance, on the card, the ship will be on a N.E. course, which makes an angle of 45° with the north.

But would the ship really be traveling on a line making a 45° angle with the geographic meridian, or direction of the north pole of the earth? She would be doing so only if the compass were absolutely correct. This is practically the case with the "gyro-compass," a mechanical contrivance now much used in the navy, but not the case with the ordinary "magnetic" compass.

In Chapters II and III, concerning dead reckoning, we have always used the word "course" as if all compasses were absolutely correct. But since they are not correct, it is now necessary to make allowance for their errors. In other words, whenever we use a compass, we must first ascertain the difference between the "true course" and the "compass course." It must not be supposed from this statement that a ship can be steered on two different courses at the same moment. There is really only one direction along which

the ship is moving: but the angle between that direction and the true north may be different from the angle between it and the "compass north." It is the course measured from the true north that must be used in all dead-reckoning calculations, and that always results from such calculations: but for steering the ship by means of a compass the steersman must be furnished with the course as measured from the compass north. Therefore it is essential for the navigator to know the difference between the two. This difference is called the "error" of the compass.

Unfortunately, this error is made up of two parts. The first, called "variation" of the compass, is due to peculiarities in the earth's magnetism, and is quite different in different places on the earth. It also varies in different years at the same place. But at any one time, all ships in the same part of the ocean will have the same variation.

The mariner can always ascertain how great the variation is in his part of the ocean, because it is always marked on his chart. Certain curved lines are drawn on the chart; and if the ship is located on or near a line marked "variation 10°," for instance, it follows that the navigator must on that day allow for 10° of variation. It is also important to take into consideration possible changes in the variation. Sometimes the annual change is marked on the chart; if not, it is important to use a chart of recent date.

The second part of the error is called "deviation" and is due to peculiarities in the magnetism always developed in the metallic parts of the ship itself. It is different in different ships, even in the same part of the ocean, and is even different in the same ship, when she is headed on different courses. Methods have been invented for "compensating" marine compasses, so as to remove the effects of deviation, and these methods are quite effective. But even when they are used, it is necessary, before beginning a long voyage, to have a "compass adjuster" visit the ship. He will then "swing" the ship on a number of different courses, and

adjust the compass so that it will be as nearly correct as possible. Finally, he will determine, by means of astronomic or other observations, just what the remaining compass deviation is on all the various courses, and give the navigator a table of these remaining deviations. This table must be taken into account in "shaping" the ship's course during the voyage. The navigator must also, from time to time, check these tabular deviations while at sea by means of astronomic observations of his own, to take care of possible changes.

Such astronomic observations are made with an instrument (the "azimuth circle"), which can be attached to the compass, and with which the "compass bearing" of the sun or any other object can be observed. The compass bearing is simply the compass direction of the object, as seen from the ship; or the compass course on which the ship would be steered, if she were moving directly toward the object. When the sun is used, its true bearing, measured from the true north, can be taken from astronomic tables which will be explained later; and it is called the sun's "azimuth." A comparison of this true bearing with that measured on the compass with the azimuth circle then makes the compass error known.

When it is not convenient to observe the sun, it is possible to substitute observations of a distant well-defined terrestrial object, whose true bearing can be measured on a chart for comparison with various compass bearings observed while the ship is being swung. Another method is to set up a compass on shore, away from any iron or steel, and use it to determine the bearing of the distant object. And there is still another method, if the above compass and the ship's compass are intervisible. For the bearing of each may then be taken from the other, and these should differ by exactly 180°. If they do not, the variation from 180° must be due to deviation on board.

The "pelorus" is another instrument which may at times replace the azimuth circle. It is located anywhere on the ship, at a convenient point for observation, and not neces-

sarily close to the compass. It has a "dummy card" and a lubber line. The dummy card can be turned until the lubber line indicates the same course as the real compass. Observations of bearings with the pelorus will then obviously be the same as if made on the compass with the azimuth circle. The advantage of the pelorus is that it can be used anywhere on board, while the compass must be kept constantly in the exact place where it was "adjusted" before leaving port.

The error thus determined astronomically or otherwise is the *sum* of the variation and deviation. If we indicate by E the total compass error in that place, at that time, on that ship, and on that course; by D the deviation similarly described; by V the variation at that time and in that place; and if all three are counted from 0° in the usual direction around the compass card, then we have the formula:

$$(1) \qquad E = V + D.$$

By counting in the usual direction, we mean counting from the north around to the east, as all courses are counted (p. 19); so that a compass error of 10°, for instance, would mean that the compass north pointed 10° east of the true north, or had a true bearing of N. 10° E. (p. 19). This is shown in Fig. 8, which also shows the ship's course, counted in the same way.

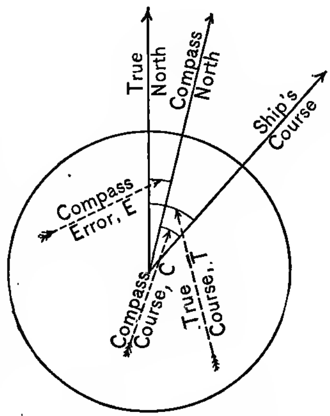

FIG. 8.—Compass Error.

It is clear from the figure that if we now indicate:
by C, the ship's compass course,
by T, the ship's true course,
by E, the compass error,
we shall have the formula:

$$(2) \qquad T = C + E.$$

The simple formulas (1) and (2) enable the navigator to make all necessary compass calculations. The following are examples.

Suppose, for instance, that the error E has been determined by observation, and the variation V taken from the chart. Formula (1) then makes it possible to calculate the deviation D. For the formula shows that E is the sum of V and D; and so D must be the difference of E and V, or:

$$D = E - V.$$

Thus the deviation D becomes known, as a check on the compass adjuster's work, and, while this value of D is correct only for the particular course on which the ship was headed at the time the observation was made, yet that course is the very one for which it is especially important to have correct information.

Again, suppose dead-reckoning calculations show that the ship is to sail on a 40° course. These calculations always furnish the true course (p. 43) so that $T = 40°$. The variation being known from the chart, and the deviation from the adjuster's table, we know from (1) $E = V + D$. Then from (2) we see that $C = T - E$, which gives the compass course. Let us suppose in the present case, that V was 9°, D 1°; then $E = V + D = 9° + 1° = 10°$; and since $T = 40°$, $C = T - E = 40° - 10° = 30°$; and the helmsman would be directed to steer a 30° course by compass.

If, in Fig. 8, the compass north happened to be 10° on the left side of the true north, instead of the right, the error E would be 350°, instead of 10° (see also fig. 7, p. 41). This might be made up of a variation V of 349° and a deviation D of 1°, as before. If the true course is again to be 40°, the compass course would be 40° − 350°, according to the formula $C = T - E$. This subtraction being impossible, we increase the 40° by a complete circumference of 360°, which is always permissible, and then have:

$$C = 360° + 40° - 350° = 50°.$$

The ship would be steered on a compass course of 50°.

An alternative way to take care of errors, variations, and deviations on the left side of the true north is to mark them with the negative or *minus* sign. Instead of calling V 349°, we might call it $-11°$. This is really the best way, and leads to the same result as before, if we remember that the subtraction of a minus quantity is always equivalent to an addition. In the example just given, calling $V - 11°$, instead of 349°, we should have: $E = V + D = -11° + 1° = -10°$; and $C = T - E = 40° - (-10°) = 50°$, the same compass course as before.

An older way of designating variations, deviations, and errors is to call them east when the compass north points to the right of the true north, and west when it points to the left of the true north. This method leads to the necessity of providing various rules or diagrams with which to make compass calculations. We think the best way to avoid error (and such errors may lose ships and lives) is to use the method here given with its two simple formulas. When some other designation of the error, or some other method of numbering the card, is demanded by a captain, it is always possible to conform to that demand, but also to translate every problem into our method (in imagination at least) as a check against mistake.

The following is an example of a compass adjuster's "deviation table," taken from Bowditch's "Navigator" (1916 edition). The deviations are set down in degrees and tenths of a degree, instead of degrees and minutes, for convenience in the further calculations. The ship was swung so that her head bore successively around the horizon, and observations were made at intervals of 15°. This is a smaller interval than is usually necessary; and the deviations in the table are much larger than commonly occur in a modern well-compensated compass.

DEVIATION TABLE

Bearing of Ship's Head by Compass	Deviation	Bearing of Ship's Head by Compass	Deviation	Bearing of Ship's Head by Compass	Deviation	Bearing of Ship's Head by Compass	Deviation
°	°	°	°	°	°	°	°
0	− 15.5	90	− 9.1	180	+ 17.9	270	+ 9.9
15	− 14.9	105	− 9.0	195	+ 23.8	285	+ 1.9
30	− 13.3	120	− 7.8	210	+ 27.1	300	− 4.2
45	− 11.3	135	− 5.9	225	+ 25.6	315	− 10.3
60	− 10.0	150	− 2.3	240	+ 22.0	330	− 13.6
75	− 9.7	165	+ 8.5	255	+ 15.9	345	− 16.0

To illustrate the use of this table, let us suppose the ship to be sailing on a compass course of 165°, in a part of the ocean where the variation is $+10°$, or 10° E. Using formula (1) (p. 45), and finding from our table that the deviation D for 165° is $+8°.5$, we have the compass error $E = V + D = +10° + 8°.5 = +18°.5$. By formula (2) (p. 45) the true course of the ship is $T = C + E = 165° + 18°.5 = 183°.5$. We should use this *true* course 183°.5 in calculating later the ship's position by dead reckoning (p. 10).

If the compass variation were everywhere the same, it would be more convenient to have a table of compass errors, instead of a table of deviations; but because the variation, as given on the chart, varies greatly, the table must be specially made for deviations only.

Equally important with the above use of our deviation table is its inverse use. When the navigator has calculated by dead reckoning the course he must steer, that course, as it comes from the calculations, will be a true course (p. 43); and it is necessary to turn it into a compass course for the use of the steersman.

To do this we must know the deviation; and we cannot get it directly from the deviation table above, because the use of that table presupposes a knowledge of the compass course, the very thing we are trying to find. The best

way to avoid this difficulty is to imagine the deviation to be non-existent, for the moment, and to make use of the "magnetic course," defined as the course which would be indicated by the compass, if deviation were thus totally absent. Under these circumstances, formula (1) gives $E = V$, since $D = 0$; and if we designate the magnetic course by M, we may write, in place of formula (2) (p. 45):

$$(3) \qquad M = T - V.$$

Let us suppose a case in which the variation is $+10°$, and the desired true course of the ship 175°. Then the magnetic course, allowing for variation only, will be, by formula (3):

$$M = T - V = 175° - 10° = 165°.$$

This course is not really a compass course, because no account has yet been taken of the deviation. Nor can we yet find the deviation directly from the deviation table, because in that table we must still know the compass course to use as the argument (p. 10), whereas we know as yet only the magnetic course. Therefore navigators should always request the compass adjuster to furnish a "second deviation table," in which the argument is the magnetic course, instead of the compass course. Such a second table can always be calculated from the other. We here give one that has been calculated from the table on the preceding page.

SECOND DEVIATION TABLE

Magnetic Bearing of Ship's Head	Deviation	Magnetic Bearing of Ship's Head	Deviation	Magnetic Bearing of Ship's Head	Deviation	Magnetic Bearing of Ship's Head	Deviation
°	°	°	°	°	°	°	°
0	− 14.9	90	− 9.0	180	+ 11.0	270	+ 16.5
15	− 13.4	105	− 8.4	195	+ 16.9	285	+ 4.1
30	− 11.7	120	− 6.9	210	+ 21.3	300	− 7.1
45	− 10.4	135	− 4.8	225	+ 24.9	315	− 13.2
60	− 9.8	150	− 1.4	240	+ 26.8	330	− 15.7
75	− 9.3	165	+ 5.0	255	+ 24.1	345	− 15.5

We also add as an example the calculation of one number in the second table from those given in the first. We shall find the deviation corresponding to the magnetic course 165°; and we do it by a kind of interpolation (p. 12). From the first table we have the deviation $-2°.3$ for the compass course 150°. Since the deviation is the only difference between compass and magnetic courses, it follows that $150° - 2°.3$, or 147°.7 magnetic, corresponds to 150° by compass. Similarly, 173°.5 magnetic corresponds to 165° by compass.

The magnetic course 165° for which we are making the calculation falls between 147°.7 and 173°.5, and exceeds the smaller of the two by 17°.3. The whole difference between 147°.7 and 173°.5 is 25°.8. Similarly, the whole difference between the two compass courses involved is 15°. Therefore we may write the proportion:

$$25°.8 : 15° = 17°.3 : x°,$$

where x is the excess over 150° of the compass course corresponding to 165° magnetic.

Solving this proportion by the ordinary rules of arithmetic, we have:

$$x = \frac{15 \times 17.3}{25.8} = 10°.0.$$

The compass course belonging to 165° magnetic is therefore $150° + 10°.0 = 160°.0$. The corresponding deviation is $165° - 160°.0 = +5°.0$,[1] which is therefore the deviation for 165° magnetic, and appears as such in the second table. This entire table can be computed from the first table in an hour.

Sometimes the second deviation table gives compass courses instead of deviations. It is then often called a "table of

[1] A comparison of formulas (1), (2), and (3) shows that $D = M - C$; so that the deviation is obtained by subtracting the compass course from the magnetic course. This is also evident from the definition of a magnetic course (p. 49).

steering courses"; and in the example just calculated it would give the compass or steering course 160° for the magnetic course 165°, instead of giving the deviation + 5°.

We shall still further illustrate this important matter by an example, supposed to occur on board a ship for which our two deviation tables hold good.

What is the compass course to be given the helmsman at Sandy Hook, on a voyage to St. Vincent?

We have already found, from dead-reckoning calculations (p. 22) the course 119°. Being the result of a dead-reckoning calculation, this is a true course. The track chart of the north Atlantic gives the variation at Sandy Hook as 10° W., or − 10°. The true course being 119°, we get the magnetic course, allowing for variation only, by formula (3), $M = T - V = 119° - (-10°) = 129°$. The second deviation table shows that:

for magnetic course 120°, the deviation is − 6°.9, and
for magnetic course 135°, the deviation is − 4°.8.

Magnetic course 129° falls between 120° and 135°, so that an interpolation (to be extremely exact) between − 6°.9 and − 4°.8 makes the deviation for magnetic course 129° come out − 5°.6. Formulas (1) and (2) now give:

$$\text{Error} = E = V + D = -10° - 5°.6 = -15°.6$$
$$\text{Compass course} = C = T - E = 119° - (-15°.6) = 134°.6.$$

To check this, we can now solve the same problem in the inverse way with the first deviation table. For the compass course 134°.6, this table gives the deviation as − 5°.9. The variation being − 10°, we have:

$$E = V + D = -10° - 5°.9 = -15°.9 \text{ and}$$
$$T = C + E = 134°.6 - 15°.9 = 118°.7,$$

agreeing very closely with the true course 119°, with which we started. This shows that the two deviation tables are quite consistent in this case, and also checks the accuracy of the calculation.

We shall close this chapter with the following little table, showing the correspondence between the two methods of dividing the compass card into points, and into degrees.

COMPASS POINTS AND DEGREES

	° ′		° ′		° ′		° ′
North	0 0	East	90 0	South	180 0	West	270 0
N. by E.	11 15	E. by S.	101 15	S. by W.	191 15	W. by N.	281 15
N.N.E.	22 30	E.S.E.	112 30	S.S.W.	202 30	W.N.W.	292 30
N.E. by N.	33 45	S.E. by E.	123 45	S.W. by S.	213 45	N.W. by W.	303 45
N.E.	45 0	S.E.	135 0	S.W.	225 0	N.W.	315 0
N.E. by E.	56 15	S.E. by S.	146 15	S.W. by W.	236 15	N.W. by N.	326 15
E.N.E.	67 30	S.S.E.	157 30	W.S.W.	247 30	N.N.W.	337 30
E. by N.	78 45	S. by E.	168 45	W. by S.	258 45	N. by W.	348 45

¼ pt. = 2° 49′ ½ pt. = 5° 38′ ¾ pt. = 8° 26′ 1 pt. = 11° 15′

CHAPTER V

COASTWISE NAVIGATION

Before proceeding to a consideration of navigation by means of astronomic observations, as it is practiced on the high seas, we must first explain certain methods by which it is possible to ascertain a ship's position in latitude and longitude while she is in sight of land. Often such methods suffice to complete a long coastwise voyage in safety; they are always important for a last determination of the ship's position before a deep-sea voyage actually begins. Such a last determination is called "taking a departure" (cf. p. 2), and from such point of departure dead-reckoning calculations begin for the first day of the voyage.

Any determination or fixing of a ship's position, by astronomic observations or otherwise, is often called, for brevity, a "fix." To obtain one while in sight of land it is customary to make observations upon well-known objects ashore, such, for instance, as lighthouses, or other conspicuous objects marked on the chart. It is always possible to observe the bearings of such objects from the ship's deck with the compass, azimuth circle, or pelorus (p. 44).

When there is but one such object in sight, it is impossible to secure a fix with ordinary instruments, if the vessel is at anchor. But if she is running, it is merely necessary to take two bearings, and to estimate the distance run by the ship in the interval between the two. Figure 9 will make this matter clear. A lighthouse ashore is at L. SS'' is the direction of the ship's course; S her position when the first bearing was observed, and S' her position at the time of the second bearing. SN is the direction of the north.

After taking the first bearing, the navigator must calculate the angle $S''SL$, between the ship's course SS'' and the lighthouse direction SL. Thus, if the ship's course angle NSS'' (p. 10) was 20°, and the bearing NSL was 42°, the angle $S''SL$ would be $42° - 20° = 22°$. As the ship proceeds on her course, the angle $S''SL$ will become larger, and a second bearing must be taken at the moment when the ship reaches the point S', where the angle $S''SL$ has become $S''S'L$. This point S' must be so chosen that the angle $S''S'L$ is just twice the angle $S''SL$ observed at S; or, in this case, 44°. This is called "doubling the bearing from the bow," and it can easily be accomplished if we continue watching the compass bearing of L as the ship goes ahead, and catch the observation at the right moment. The ship's course not having been changed from 20° (this is important), the right moment will occur when L bears $20° + 44° = 64°$ by the compass.

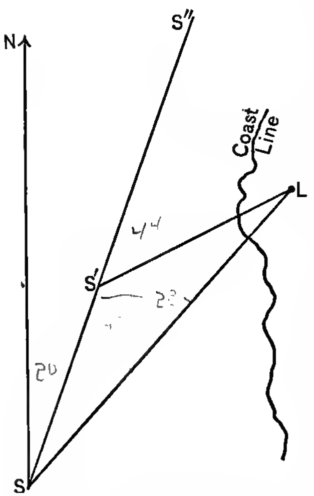

FIG. 9.—Ship's Position by Two Bearings.

It can easily be proved by geometry that the distance $S'L$ between the ship at S' and the lighthouse at L will be equal to the distance SS' traveled by the ship in the interval between the two observations. This distance can be estimated quite accurately with an instrument called a "log," or "patent log," which is towed astern of the ship. It is so constructed that it turns as it is pulled through the water, and the number of turns is automatically counted by an attached contrivance on deck. The count is (also automatically) turned into miles of distance; so that the log on deck will indicate how far the ship traveled from S to S'.

As soon as we know the distance $S'L$ and the bearing of the line $S'L$, we can "lay down" or "plot" the position of S' on the chart; and this will be a "good fix." To do this, let us indicate by B' the bearing of the line $S'L$, and then draw on the chart, through the lighthouse L, a pencil line whose bearing from L is $B' + 180°$, or "B' reversed." This can be done with a "course protractor," or with "parallel rulers," instruments to be purchased from any dealer in navigators' supplies. Next we measure or "lay off" on that line the distance $S'L$, equal to the run SS' as it came from the log. We always know the right "scale" of the chart (or fraction of an inch corresponding to one logged mile) which must be used in laying off the distance $S'L$; for we know that one mile always corresponds to 1 minute of latitude (p. 15), and the right- and left-hand edges of the chart are always divided into degrees and minutes of latitude.

Since the above bearings were observed by compass, it is now important to consider the compass error (p. 43). This will not affect the observations, because it will be the same for both ship's course and lighthouse bearing, so the angles $S''SL$ and $S''S'L$, which are obtained by subtraction, will be the same as if there were no compass error. But when we come to plotting on the chart, the compass bearing B' must be corrected by adding the deviation from the deviation table (pp. 48, 49). The resulting magnetic bearing (p. 49) must be used for B', if the chart has printed on it a compass card (p. 41) showing magnetic bearings. If the printed card shows true bearings only, B' must be corrected for both deviation and variation (p. 43).

A specially important case of the foregoing occurs when the two angles $S''SL$ and $S''S'L$ are 45° and 90°. The second bearing B' will then put the light just abeam, and the distance by log, SS', is the distance at which the ship passes the light abeam. This case is called a "bow-and-beam bearing." The navigator sights the light when it bears 45° or 4 points (p. 52) "broad" on the bow, "starboard,"

or "port." He then "reads" the log. When he brings the light abeam through the motion of the ship, he reads the log again, and the run in the interval, as taken from the log, is the light's distance abeam.

When sailing along the coast, it is particularly important so to shape the ship's course that lights and other prominent landmarks will be passed at the right distance abeam. The chart shows what the right distance is: if the navigator shapes a course which makes the distance abeam too small, he may fail to clear rocks or shoals extending seaward; and if he makes it too large, he may lengthen his voyage unnecessarily in rounding the light.

There are certain pairs of angles ($S''SL$ and $S''S'L$) which will make known the coming distance abeam long before the ship is dangerously near the light. These angles, $S''SL$ and $S''S'L$, are called "bearings from the bow" (see p. 54), since they are really measured from the ship's bow instead of the north. If the two bearings from the bow are either of the following pairs:

22° and 34°,	32° and 59°,
27° and 46°,	40° and 79°,

then the logged distance in the interval between the two observations is the distance at which the ship will pass the light abeam if she continues on her present course. This kind of observation will inform the navigator whether his course is safe in ample time to change it if necessary; and, since in this case no bearings are marked on the chart, no attention need be paid to compass error.

When two or more known and conspicuous landmarks are visible from the ship, it is possible to secure a fix by means of "cross-bearings." Observe the bearings of the objects as nearly simultaneously as possible. Allow for compass error in the manner just explained. Calculate for each object a reversed bearing by adding 180° to its observed bearing. Draw on the chart through each object

a pencil line having the proper reversed bearing and these lines will intersect at the point on the chart where the ship is located. Figure 10 illustrates this matter. L, L', L'' are lights or landmarks ashore, visible from the ship, and also printed on the chart. The ship is at S. The lines intersecting at S represent the reversed bearings of L, L', L'', as observed from S. Only two lines are necessary; and they should be chosen so that the angle between them is as near a right angle as possible, if high accuracy is required in the fix. The third object and line merely serve as an additional check or safeguard against error.

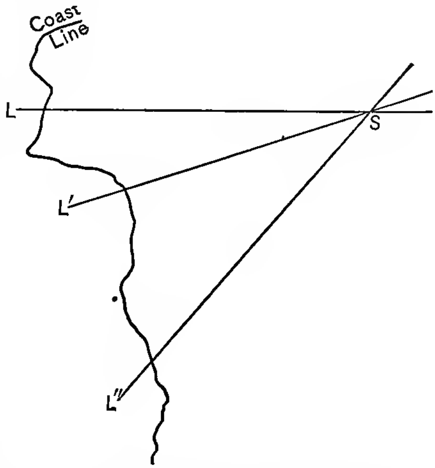

FIG. 10. — Ship's Position by Cross Bearings.

In addition to the foregoing methods of locating a ship by observations of objects ashore, there is a way to avoid sunken rocks or shoals without actually locating the ship on the chart. It is called the "danger angle," and is shown in Fig. 11. The small circle is supposed drawn on the chart around a rocky shoal K which must be cleared by the ship traveling along the course SS'. To make certain of clearing it safely, the navigator selects two visible objects ashore, and shown on the chart at L and L'. He draws on the chart a large circle passing through L and L', and just touching the dangerous small circle at T. There is no difficulty in finding the center of the large circle, because it must be somewhere on the line PQ, which is drawn at right angles to the line LL' at its middle point P. A few trials with a

pair of compasses will locate the center. Next, the two lines LT and $L'T$ are drawn. Then the angle LTL' is called the danger angle.

Now it is a principle of geometry that if we select other points on the large circle, such as T' and T'', the angles

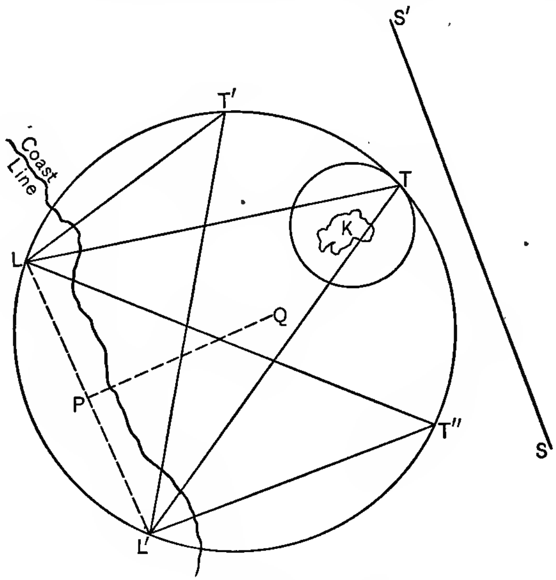

FIG. 11.—The Danger Angle.

$LT'L'$, $LT''L'$, etc., will all be equal, and will contain the same number of degrees as the danger angle LTL'. It follows that if the navigator measures from the deck the angle formed by two lines drawn to the ship from L and L', and if he finds it equal to the danger angle LTL', as measured on the chart with a protractor (p. 55), he then knows that the ship is somewhere on the large circle, and is therefore perhaps too near the small dangerous circle. If, on the other hand, the ship is entirely outside the large circle, and therefore surely safe from the dangers of the small circle,

the measured angle at the ship between the objects L and L' will always be smaller than the danger angle LTL'.

Angles can be measured from the deck by taking compass bearings of L and L'. The difference of the two will be the deck angle, which should be smaller than the danger angle measured on the chart. But the very best way to measure the deck angle is to use the sextant, an angle-measuring instrument to be described later (p. 61).

The danger angle can also be used when it is necessary to pass *between* a sunken danger circle and the shore. The large circle is then drawn through L and L' as before, but in such a way as just to touch the inside of the small circle instead of the outside. To pass inshore of the small circle it is then necessary for the navigator to keep his measured deck angle *larger* than the danger angle, instead of smaller.

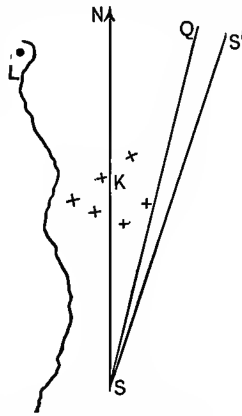

FIG. 12.—The Danger Bearing.

Navigators also use at times a means of safety known as the "danger bearing," illustrated in Fig. 12. There is but one charted object in sight ashore at the point L. The ship at S must steer in such a way as to avoid sunken rocks at K. Evidently, she must pass outside the line SQ, of which the bearing from the north is the angle NSQ, which can be measured on the chart. This is the danger bearing, and the ship's course SS', to be safe, must be *greater* than the danger bearing. In the case shown in the figure, the danger bearing would be very useful long before a fix could be had by means of bearings from the bow or bow-and-beam bearings.

Finally, to complete this part of our subject, it is necessary to mention "soundings," which are a method of *feeling* the land, even when it cannot be seen. By means of

the "lead-line" the mariner can ascertain when he is in shoal water; and as depths of water are always marked on the chart, he can often get valuable information as to the ship's position. As she runs along her course, he can take a "line of soundings" and upon examining the chart he will often find but a single possible line on the chart where the charted depths correspond with those observed. It follows that the ship's course must have been along that line on the chart; and at an anxious moment, in a fog, such a check will be a great relief to the navigator. Even in the ocean, far from land, it is possible to take soundings with the "sounding machine" at great depths, and in some parts of the ocean quite accurate locating of the ship will result. Specimens from the ocean floor can also be brought up by attaching some sticky grease to the bottom of the lead, and at times these specimens also give information of value, for the charts always specify the kind of bottom existing in various parts of the ocean.

CHAPTER VI

THE SEXTANT

We have twice made reference to this instrument — once (p. 5) as a contrivance for ascertaining by observation how high the sun is in the sky, and again (p. 59) in the measurement of the danger angle. These two uses of the sextant are not inconsistent, for it is really intended for the measurement of any angle (p. 8) formed at the observer's eye by two lines drawn to two distant objects. In the case of the danger angle these two distant objects are landmarks ashore; in the case of the sun they are the "horizon" line (where sea and sky seem to meet), and the sun itself. This height of the sun (or of any star) in the sky is called its "altitude"; and so the altitude is always an angle, to be measured in degrees and minutes. The point directly overhead is the "zenith"; the angle between lines drawn to horizon and zenith is 90°, or a right angle. An altitude of 40°, for instance, simply means that the distance from the horizon to the sun is $\frac{40}{90}$ of the total distance from horizon to zenith.

Figure 13 will give an idea of the construction of the sextant.[1] The essential parts are two small silvered mirrors, *M* and *m*; a telescope, *EK*; and a circle, *AA*, engraved with "graduations," by means of which angles may be measured upon it in degrees, minutes, and seconds. The mirror *m* and the telescope *EK* are firmly attached to the sextant; but the mirror *M* is pivoted in such a way that it

[1] Quoted in part from Jacoby's "Astronomy, a Popular Handbook," Macmillan, 1913; reprinted 1915.

can be turned, and the angle through which it is turned measured on the circle by means of the index *CB*. When the mirror *M* is turned until it is parallel to the fixed mirror *m*, the circle "reads" or indicates 0°, because the angle between the two mirrors is then 0°. In all other positions

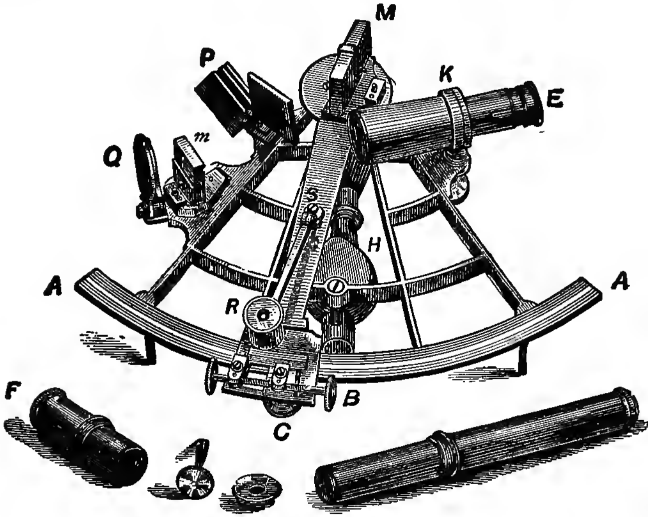

FIG. 13.—The Sextant.

of the mirror *M* the circle measures the angle between the two mirrors. *P* and *Q* are sets of colored glasses, which can be interposed temporarily, when the sun's rays are so brilliant as to be hurtful to the observer's eye. *R* is a small magnifying glass, pivoted at *S*, intended to facilitate the examination of the index *CB*. At *C* and *B* are shown the "clamp," by which the index can be fastened to the circle, and the "tangent screw," or "slow-motion screw" which will adjust it delicately, after it has been clamped. *I* and *F* are additional telescopes or accessories.

The mirror *m* has an important peculiarity. The silvering is scraped away at the back of the mirror from half its

surface. Thus only one half reflects; the other half is simply transparent glass. A navigator looking into the telescope at E will therefore look *through* the mirror m with half his telescope, and with the other half he will look *into* the mirror.

Now it is a fact that half a telescope acts just like a whole one. If a person using an ordinary spy-glass half covers the big end with his hand, he will see the same view he saw with the whole glass. Only, as half the "light-gathering" power is cut off, this view will be fainter, — less luminous. Applying this to the sextant telescope, it is clear that the observer will see *two* things at once: with half the telescope he will see what is visible *through* the mirror m; and with the other half he will see what is visible by reflection *from* the mirror m.

If he holds the sextant in such a position that the telescope is horizontal, while the frame of the instrument is vertical, he will see the visible sea horizon with half the telescope *through* the mirror m. If the other mirror M is then turned to the proper position, it is possible to see the sun in the sky at the same time, with the other half of the telescope, the solar rays having been reflected successively from *both* mirrors, M and m. To make this possible, the sextant telescope must be aimed at that point of the sea horizon which is directly under the sun. The solar rays will then strike the mirror M first; be thence reflected to the silvered part of the mirror m; and finally reflected a second time *into* the telescope. Therefore the observation consists in so turning the movable mirror M, that the sun and horizon can be seen coincidently in the telescope.

The angle between the mirrors can then be measured on the circle; and it is easy to prove by geometry that the angular altitude of the sun will be twice the angle between the two mirrors. Thus it should merely be necessary to double the mirror angle, as indicated by the sextant index, to obtain the solar altitude. But the sextant makers always

save the navigator the trouble of doubling the angle by the simple device of numbering half degrees on the arc *AA* as if they were whole degrees; so the angle as it comes from the sextant is already doubled for further use. The mirror *m* is called the "horizon glass," because the navigator looks through it at the horizon. The other mirror *M* is the "index glass," because it is attached to the index arm.

When the sextant is used for non-astronomical observations, such as the danger angle, the frame is held horizontally, instead of vertically, as in observations of the sun. The telescope is aimed at the left-hand object ashore, and that object is viewed *through* the horizon glass *m*. The index glass *M* is then turned until light from the right-hand object is also brought into the telescope, after successive reflections from the two mirrors *M* and *m*. The two objects will then be seen "superposed," and the sextant arc will give the angle between two lines drawn from the observer on board to the two objects ashore. This angle should be smaller than the danger angle to keep the ship safely off-shore of sunken dangers (p. 59).

Reading the sextant circle, or ascertaining from it the angle that has been measured, is accomplished by means of a "vernier." This is a short circular arc, engraved with graduations resembling those on the sextant circle, attached to the index *CB* (fig. 13) just under the little magnifier *R*. It is so placed that the graduations on the sextant circle and the vernier are close together and can be seen at the same time through the magnifier *R*. Figure 14 gives an idea of the vernier and a part of the sextant circle near the zero of its graduations. Numbers on both circle and vernier increase toward the left. On the circle, the largest spaces, marked by long lines, are whole degree spaces. Each is usually divided into two halves of 30′ each indicated by shorter lines, and these are again subdivided into three small spaces of 10′ each. The divisions on the vernier resemble those on the circle, except that the degree spaces

of the former are here called minute spaces, and the 10′ spaces of the former are called 10″ spaces.

The real index of the instrument is the zero mark on the vernier, sometimes provided with an engraved "arrow." If this falls exactly on a degree mark of the circle, say the 1° mark, the reading of the instrument is exactly 1° 0′ 0″. If it falls exactly on a small line of the circle, say the second to the left of the 1° mark, the reading is exactly 1° 20′ 0″. But if it falls *between* two of the small lines, say between the 20′ and 30′ marks to the left of the 1° mark (as shown in the figure), the reading must be 1° 20′ *and a "bit."* It is the business of the vernier to estimate the size of that bit. To do this look along the vernier until you find a line which is exactly opposite some line on the circle. There will always be such a line: in the figure it is the 6′ line of the vernier. Pay no further attention to noting which line on the circle is the one thus "exactly opposite"; it matters not which line it is. But read carefully the number *on the vernier* belonging to the "exactly opposite" line you have found there. Being on this occasion the 6′ line, it follows

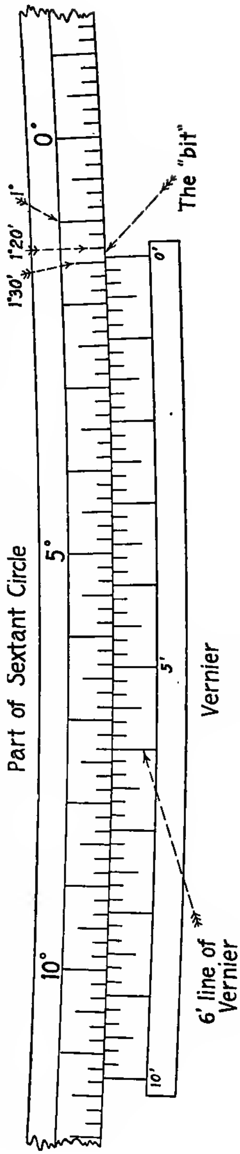

FIG. 14.—The Vernier.

that the bit is 6′; and as we found the reading to be 1° 20′ and a bit, the complete reading is 1° 20′ + 6′ = 1° 26′.

If the vernier line that happened to be "exactly opposite" was not one of the ten long minute lines, but fell between two of them, it would indicate that the bit was made up of minutes and seconds, instead of being an exact number of minutes. For each space the "exactly opposite" vernier line happens to lie to the left of a long vernier minute line, 10″ must be added to the bit. For instance, if in the figure the "exactly opposite" vernier line was the next short one to the left of the 6′ long line, the bit would be 6′ 10″, and the complete reading 1° 26′ 10″, instead of 1° 26′. But seconds are not really required when observing aboard ship, so that it will be sufficient, in using the vernier, to find the number of the long vernier line that comes nearest to being "exactly opposite."

It will also be noticed in the figure that the sextant circle has some additional graduations to the *right* of the 0° mark. These are called "off the arc" graduations, and it is sometimes necessary to read a small angle upon them, measuring from the 0° mark to the right instead of the left. This makes it necessary to read the vernier backwards, calling the 0′ mark of the vernier 10′ and the 10′ mark 0′.

This backward reading of the vernier offers no particular difficulty, and it is especially useful in determining by observation the "index error" of the sextant. We have seen (p. 62) that when the two sextant mirrors are parallel, the index should read 0° 0′ 0″. But it is seldom possible to adjust the instrument so that this condition will be satisfied exactly; nor would the adjustment remain perfect *very long*. A better plan is to determine by observation how much the reading differs from 0° 0′ 0″, when the mirrors are parallel. This difference is the index error, and must be applied as a correction to all angles observed with the instrument.

It is easy to make the mirrors parallel: we have merely

to sight some distant well-defined terrestrial object like the gilt ball on the top of a flagpole (or the sea horizon, if aboard ship at sea), after clamping the index near 0°. We shall then see in the telescope two images of the distant object; one by direct vision through the unsilvered part of the horizon glass, the other after reflection from *both* mirrors. By means of the tangent screw, the observer, with his eye at the telescope, can bring these two images together, so that they will appear as a single image. Then the mirrors will be parallel, and the vernier should read 0° 0′ 0″. If it actually reads 0° 8′, for instance, instead of 0° 0′ 0″, it means that the reading is 8′ too large on account of index error; and *every* angle measured with that sextant at that time will be 8′ too large, and must be corrected by subtracting 8′ from it.

If, on the other hand, the reading is 8′ "off the arc," when it should be 0° 0′, the instrument reads 8′ too small, and any angle measured with it must be corrected by adding 8′ to it.

For accurate determination of the index error (and it should be checked frequently), navigators prefer to observe the sun, or at night, a star. If a star is used, the process is the same as just described for a flagpole ball. But if the sun is used, a slightly different method is required. The sun, as seen in the telescope, shows a round disk of considerable size, and it is not possible to superpose the two images accurately. Therefore it is better to make them just touch, as shown in Fig. 15, when they are said to be "tangent" to each other. This must be done successively in two positions, *AB* and *BA*. In other words, after the first "tangency" has been observed, the tangent screw (*B*, fig. 13) is manipulated until the image *A* passes across *B* from top to bottom, and gives a new tangency in the second position.

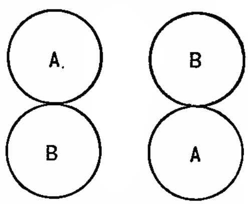

FIG. 15. — Index Error.

Each tangency will give a reading of the vernier. Unless

the sextant is greatly out of adjustment, one of these readings will be off the arc, the other on the arc. If there were no index error, the off-arc and on-arc readings would be equal; if they differ, half the difference is the index error. If the off-arc reading is the larger, all altitudes measured with that sextant must be *increased* by the amount of the index error; and if the on-arc reading is the larger, all such altitudes must be similarly diminished.

The following is an example of an index error determination:

	On-arc readings,	Off-arc readings,
	31′ 20″	33′ 20″
	31 40	33 50
	30 50	34 0
Means,	31′ 17″	33′ 43″

The difference is $33' \ 43'' - 31' \ 17'' = 2' \ 26''$. Half the difference, or $1' \ 13''$, is the index error; and because readings on the arc are the smaller, all angles read with this instrument must be *increased* by $1' \ 13''$, or, for ordinary purposes of navigation, by $1'$.

In addition to certain "adjusting screws" with which the index error can be reduced when it becomes unduly large, means are provided for three other sextant adjustments. These are:

1. To make the index glass perpendicular to the frame of the instrument.
2. To do the same with the horizon glass.
3. To set the telescope parallel to the frame of the instrument.

These adjustments are always completed by the maker before a sextant is sent out, nor does the navigator usually need to correct them himself. But it is important to know how to test them occasionally. Perpendicularity of the index glass can be examined by looking into the glass very obliquely with the index set near 0°. It is then possible to see the inner edge of the sextant circle both by looking at

it directly, past the edge of the index glass, and also by reflection in the glass itself. The inner edge of the circle should form a continuous line when so examined, if the glass is perpendicular; but if it is inclined, the line will appear broken, instead of continuous.

Secondly, perpendicularity of the horizon glass can be tested at the same time the index error is determined by observing a star or a distant terrestrial point (p. 67). The index glass having been properly adjusted to perpendicularity, the two mirrors can never be made parallel by moving the index, unless the horizon glass is also properly perpendicular. Any existing lack of adjustment will therefore betray itself in the index error determination, because the two images of the star or distant object will not be superposed in *any* position of the index.

Thirdly, the parallelism of the telescope to the frame of the instrument can usually be best tested with an ordinary pair of "calipers."

Having thus described the sextant, its adjustments, and its use from the deck, we have still to explain how it can be used ashore. Sometimes it is necessary for the navigator to make observations ashore, when it is not usually possible to see the horizon line (p. 61). Recourse must then be had to an "artificial horizon," which is simply an iron basin full of mercury covered with a glass roof. The mercury furnishes an almost perfectly horizontal mirror, and the glass roof prevents wind from ruffling the mercury surface, and thus destroying the mirror. Figure 16 explains the principle of the artificial horizon. *HH* is the mercury mirror, *S* the sun, and *X* the sextant. The observer aims the sextant telescope at the mercury where he can see a reflection of the sun. He then measures with the instrument the angle between a line

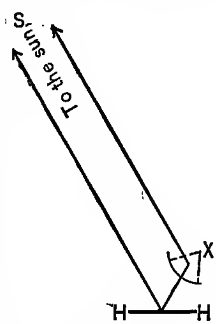

FIG. 16. — Artificial Horizon.

drawn to the sun as seen reflected in the mercury and another line drawn to the actual sun in the sky. It can be shown by geometry that this measured angle will be just twice the real altitude of the sun, such as it would be if observed from the sea horizon. Therefore, in using the artificial horizon, it is merely necessary to divide the sextant angle by 2 to obtain the correct altitude of the sun.

In observations of this kind two "suns" are seen at the same time in the telescope, just as is the case in index error observations (p. 67); whereas in observing from the sea horizon, the telescope shows only one solar image and the horizon line. When there are thus two solar images, they must be brought into tangency, just as we have already explained for index error (p. 67). When there is but one, it must be brought into tangency with the visible sea horizon line.

But this altitude is not yet ready to be used in the further calculations for obtaining the position of the ship in latitude and longitude. Further preparatory corrections must be applied, in addition to the index error (p. 66), which is always the first correction to receive attention. These preparatory corrections are:

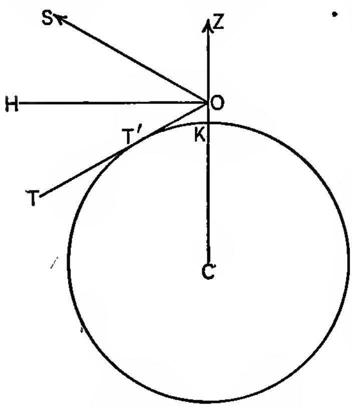

FIG. 17.—Dip of the Horizon.

1. "Dip" of the sea horizon, due to the elevation of the navigator on the ship's deck above the surface of the sea. Its cause is shown in Fig. 17. *C* is the center of the earth, *K* a point at sea level, and *O* the navigator, elevated a distance *OK* above the sea. *OZ* is the direction of the zenith (p. 61), *OS* the direction of the sun, and *OH* a horizontal line from *O*. *OT* is a line drawn through *O*, and just touch-

ing the sea surface at T'. Evidently OT will be the direction of the sea horizon, where sky and sea seem to meet. Therefore, the altitude of the sun, as measured from the visible sea horizon, will be the angle SOT; whereas the angle we require is the angle SOH, or the altitude of the sun above the true horizontal line OH. Therefore the angle HOT is a correction for dip which must be subtracted from all measured altitudes, and the amount of the correction depends on the height of the navigator's eye above the sea surface.

2. "Refraction" is a bending of the light rays as they come down to us from the sun through the terrestrial atmosphere. It always makes the sun seem higher in the sky than it really is, giving another subtractive correction for the observed altitude. The bending here involved is due to the passage of the sun's light rays through atmospheric strata of increasing density as the light approaches the earth's surface.

3. "Parallax" is a small correction which must be added to the observed altitude of the sun. In strict theory, all astronomic observations are supposed to be made from the earth's center instead of its surface where the ship floats; and the small parallax correction allows for this minor theoretic point. In the case of star observations this correction is zero.

4. "Semidiameter" is a correction depending on the choice by the navigator of a particular point on the sun's disk (p. 67) for observation. The sun's altitude, as used in the further calculations, should be the altitude of the sun's center; but it is impossible to locate the center of the disk accurately in the telescope, so the navigator always observes the lowest point of the disk. This is called the "lower limb" of the sun.

Beginners sometimes have difficulty in distinguishing the upper from the lower limb in the telescope. The best way to do this is to focus the telescope on some distant

object, and note whether it appears upside-down in the field of view. If so, the telescope is an "inverting" one, and the top of the sun must be observed, as it appears in the telescope, though it will really be the correct (or lower) limb, because of inversion by the telescope. When using the artificial horizon with an inverting telescope, the tangency must be made by bringing the bottom of the mercury image in contact with the top of the other image. The high-powered telescopes supplied with good sextants are usually inverting telescopes.

Evidently the measured altitude, as it comes from the sextant, must be increased by the amount by which the sun's center is higher than the lower limb, and this is the sun's semidiameter. The index correction, together with the above four additional corrections, will fully prepare a measured sextant altitude of the sun for further use in navigational calculations. In the case of a star, which appears in the telescope as a point of light only, without any perceptible disk, no semidiameter or parallax corrections are required; and in using the artificial horizon (p. 69), no correction for dip is necessary, either for the sun or a star.

It is possible to arrange these various corrections in convenient tables. Thus, in Table 6 (p. 247), we give a combination of corrections 2 (refraction), 3 (parallax), and 4 (semidiameter), to be used for observations of the sun's lower limb, and the same combination without the semidiameter and parallax[1] to be used for star observations. It will be noticed that the tabular corrections vary for different values of the observed altitude, which appears in the left-hand column of the table. This variation comes mainly from the refraction part of the combined correction, for the refraction is much greater when the sun or star is observed at a low altitude near the horizon than it is at a high altitude near the zenith. At the foot of the page is given a small supplementary correction depending on the date in the year.

[1] Which leaves refraction only.

This small correction is not important in navigation, but is given here for the sake of completeness. It arises from the semidiameter part of the combined correction, for the annual orbit of the earth around the sun is of such a shape that the earth is nearer the sun in January than it is in July, which makes the sun appear bigger in January. And when the sun appears big, the semidiameter will of course be large too.

Table 7 gives the dip of the sea horizon, the number in the left-hand column being the height (in feet) of the navigator's eye above sea level. This will be the height of the ship's deck, increased by the height of the man's eye above the deck. Unfortunately, the dip, as given in Table 7, at times varies considerably from the dip as it actually exists at the ship. The cause can be seen from Fig. 17 (p. 70), where it will be noticed that the line from the observer at O to the sea horizon at T' passes very near the surface of the ocean. It is therefore entirely in the lowest strata of the terrestrial atmosphere, and there quite irregular refractions sometimes occur. These have been known to produce errors in the dip amounting to 10′ or 20′, and it is principally the existence of these unavoidable errors that makes it unnecessary to read the sextant closer than the nearest minute (p. 66), when observing from the deck. But when observing ashore with the artificial horizon, which has no dip, the navigator may, if he chooses, read seconds, especially if he intends to use in his further calculations the "mean" or average of a considerable number of observations.

We shall now give an example of the complete correction of a sextant observation. Suppose the angle read from the sextant was 30° 28′, the index error (p. 68) 1′, additive, height of observer's eye 26 feet. We should then have:

observed altitude, lower limb	= 30° 28′
index correction	= + 1′
correction from Table 6 (p. 247)	= + 14′
correction from Table 7 (p. 247)	= − 5′
corrected altitude, for further use	= 30° 38′

If the altitude had been observed ashore with an artificial horizon, it might have been desirable to retain seconds. The calculation might then have been as follows:

observed *double* altitude (see p. **70**), lower limb	=	63°	0′	20″
index correction (p. 68)	=		+ 1	13
corrected double altitude	=	63	1	33
resulting altitude	=	31	30	46
correction from Table 6 (interpolated)	=	+	14	31
corrected altitude, for further use	=	31	45	17

CHAPTER VII

THE NAUTICAL ALMANAC

BEFORE beginning the further utilization of altitude observations in our navigation calculations, it is necessary to understand the use of the Nautical Almanac. This is an annual publication, issued in two different editions by the Nautical Almanac Office, United States Naval Observatory. Copies can be obtained from the Superintendent of Documents, Washington, D. C., or through any dealer in nautical supplies. Navigators do not need the larger edition, of which the title is "American Ephemeris and Nautical Almanac"; accordingly, all our references are made to the smaller edition for the year 1917. Parts of certain pages from that edition are reprinted in the present volume for convenience of reference, and we shall give a somewhat detailed explanation of the almanac page 29 (our p. 76).

Let us consider the date Monday, Dec. 17. We find for that date, and for every even hour (0^h, 2^h, 4^h, 6^h, etc.) of "Greenwich Mean Time" (abbreviated G. M. T.[1]), two tabular numbers (p. 10) called "sun's declination" and "equation of time."

To understand these it is necessary to bear in mind that the kind of time in ordinary use is "solar time," as kept by the sun. The "solar day" begins at "noon," called 0^h in astronomic navigation, and it continues through twenty-four hours, without any confusing A.M. and P.M. In ordinary life the day begins twelve hours sooner, at midnight, and runs through two twelve-hour periods of A.M. and P.M. to

[1] The reader is requested to note carefully this abbreviation, as it will be used very frequently.

SUN, DECEMBER, 1917. *From* Nautical Almanac, p. 29

G. M. T.	Sun's Declination	Equation of Time	Sun's Declination	Equation of Time	Sun's Declination	Equation of Time
	Monday 17		Tuesday 25		Saturday 29	
h	° ′	m s	° ′	m s	° ′	m s
0	− 23 21.3	+ 3 56.8	− 23 24.7	− 0 1.6	− 23 15.2	− 1 59.7
2	23 21.5	3 54.4	23 24.6	0 4.1	23 14.9	2 2.1
4	23 21.7	3 51.9	23 24.5	0 6.5	23 14.6	2 4.6
6	23 21.9	3 49.5	23 24.4	0 9.0	23 14.3	2 7.0
8	23 22.1	3 47.0	23 24.2	0 11.5	23 14.0	2 9.4
10	23 22.2	3 44.5	23 24.1	0 14.0	23 13.7	2 11.9
12	23 22.4	3 42.1	23 24.0	0 16.5	23 13.4	2 14.3
14	23 22.6	3 39.6	23 23.8	0 18.9	23 13.1	2 16.7
16	23 22.8	3 37.1	23 23.7	0 21.4	23 12.8	2 19.1
18	23 22.9	3 34.7	23 23.5	0 23.9	23 12.5	2 21.5
20	23 23.1	3 32.2	23 23.4	0 26.4	23 12.2	2 24.0
22	23 23.2	3 29.8	23 23.2	0 28.8	23 11.9	2 26.4
H. D.	0.1	1.2	0.1	1.2	0.1	1.2
	Tuesday 18		Wednesday 26		Sunday 30	
0	− 23 23.4	+ 3 27.3	− 23 23.1	− 0 31.3	− 23 11.6	− 2 28.8
2	23 23.6	3 24.8	23 22.9	0 33.8	23 11.3	2 31.2
4	23 23.7	3 22.3	23 22.7	0 36.3	23 11.0	2 33.6
6	23 23.8	3 19.9	23 22.5	0 38.7	23 10.6	2 36.0
8	23 24.0	3 17.4	23 22.4	0 41.2	23 10.3	2 38.4
10	23 24.1	3 14.9	23 22.2	0 43.7	23 10.0	2 40.9
12	23 24.3	3 12.5	23 22.0	0 46.2	23 9.7	2 43.3
14	23 24.4	3 10.0	23 21.8	0 48.6	23 9.3	2 45.7
16	23 24.5	3 7.5	23 21.7	0 51.1	23 9.0	2 48.1
18	23 24.6	3 5.0	23 21.5	0 53.6	23 8.6	2 50.5
20	23 24.8	3 2.6	23 21.3	0 56.0	23 8.3	2 62.9
22	23 24.9	3 0.1	23 21.1	0 58.5	23 7.9	2 55.3
H. D.	0.1	1.2	0.1	1.2	0.2	1.2
	Wednesday 19		Thursday 27		Monday 31	
0	− 23 25.0	+ 2 57.6	− 23 20.9	− 1 0.9	− 23 7.6	− 2 57.7
2	23 25.1	2 55.1	23 20.7	1 3.4	23 7.2	3 0.1
4	23 25.2	2 52.6	23 20.5	1 5.9	23 6.9	3 2.4
6	23 25.3	2 50.2	23 20.3	1 8.3	23 6.5	3 4.8
8	23 25.4	2 47.7	23 20.1	1 10.8	23 6.1	3 7.2
10	23 25.5	2 45.2	23 19.8	1 13.2	23 5.8	3 9.6
12	23 25.6	2 42.7	23 19.6	1 15.7	23 5.4	3 12.0
14	23 25.7	2 40.2	23 19.4	1 18.1	23 5.0	3 14.4
16	23 25.8	2 37.8	23 19.2	1 20.6	23 4.6	3 16.7
18	23 25.9	2 35.3	23 19.0	1 23.1	23 4.3	3 19.1
20	23 26.0	2 32.8	23 18.7	1 25.5	23 3.9	3 21.5
22	23 26.1	2 30.3	23 18.5	1 28.0	− 23 3.5	− 3 23.9
H. D.	0.0	1.2	0.1	1.2	0.2	1.2
	Thursday 20		Friday 28			
0	− 23 26.1	+ 2 27.8	− 23 18.3	− 1 30.4		
2	23 26.2	2 25.3	23 18.0	1 32.9		
4	23 26.3	2 22.8	23 17.8	1 35.3		
6	23 26.3	2 20.4	23 17.5	1 37.8		
8	23 26.4	2 17.9	23 17.3	1 40.2		
10	23 26.5	2 15.4	23 17.0	1 42.6		
12	23 26.5	2 12.9	23 16.8	1 45.1		
14	23 26.6	2 10.4	23 16.5	1 47.5		
16	23 26.6	2 7.9	23 16.3	1 50.0		
18	23 26.7	2 5.4	23 16.0	1 52.4		
20	23 26.7	2 2.9	23 15.7	1 54.8		
22	− 23 26.8	+ 2 0.4	− 23 15.4	− 1 57.3		
H. D.	0.0	1.2	0.1	1.2		

SEMIDIAMETER

Dec. 1	16′26
11	16′28
21	16′29
31	16′30

NOTE. — The Equation of Time is to be applied to the G. M. T. in accordance with the sign as given.

the following midnight; but this "civil day," as it is called, does not for the moment concern us.

Solar time, as kept by the *visible sun,* is a very inconvenient kind of time, because there are certain peculiarities in the astronomic motion of the earth which make these solar days of unequal length. They are called "apparent solar days" and the corresponding kind of time is "apparent solar time."

To avoid the above inconvenience, an imaginary "mean sun" and a "mean solar day" have been invented. The mean sun conforms as nearly as possible to the average performance of the visible sun, and the length of the mean solar day is the average of all the apparent solar days throughout the year. The corresponding kind of time, kept by the mean sun, is "mean solar time"; and this is the kind of time recorded by all our watches and marine chronometers (p. 6).

The difference between these two kinds of solar time varies on different dates, and even at different hours on the same date. It is this difference which is called the "equation of time" and which is one of the tabular numbers in the nautical almanac page 29 (our p. 76).

This equation of time is of great importance in navigation, and it is easy to see how page 29 of the almanac may be used to find it. Suppose, for instance, we wish to know what the equation is on Dec. 17, 1917, on board ship, when the ship's chronometer indicates on its face 3 P.M., civil time, or (which is the same thing) 3^h, astronomical time (p. 75). Ship's chronometers are always set to Greenwich mean time, so that 3^h by the chronometer signifies that the time at Greenwich was 3^h.

We then look in the almanac page 29 (our p. 76), and find that the equation was $+ 3^m\ 54^s.4$ at 2^h, G. M. T., and $+ 3^m\ 51^s.9$ at 4^h, G. M. T. Its value at 3^h must be halfway between these two, or $+ 3^m\ 53^s.15$. This we would call $+ 3^m\ 53^s.2$, so as to avoid the use of hundredths of seconds, which do not need attention in navigation. And

since the equation is merely the difference between the two kinds of solar time, the + sign means that it must be *added* to G. M. T., to obtain Greenwich apparent time, in accordance with the "Note" at the foot of the almanac page 29. Consequently, the G. M. T. by chronometer having been $3^h\ 0^m\ 0^s$, the Greenwich apparent time at the same instant was $3^h\ 0^m\ 0^s + 3^m\ 53^s.2 = 3^h\ 3^m\ 53^s.2$.

It will be noticed that the process we have here used for obtaining the equation from the almanac is merely an interpolation (see p. 12). Let us, as another example, find the equation for Sunday, Dec. 30, at $10^h\ 26^m$ A.M., civil time by chronometer, and we have purposely here retained the civil method of reckoning time to make certain that the reader understands the difference between civil and astronomic (or navigation) time. The given time is $10^h\ 26^m$ A.M., civil time, Dec. 30. But the astronomic Dec. 30 does not begin until noon (p. 75), so that it is not yet Dec. 30 by astronomic reckoning. By that reckoning it is really only $22^h\ 26^m$ on Dec. 29. In other words, when the civil time is P.M., as in the first example, the astronomic time is the same as the civil time. But when the civil time is A.M., as in the present example, the astronomic time is found by adding 12^h to the civil time, and deducting 1 from the date. These complications emphasize the advantage of the astronomic count, which avoids A.M. and P.M. altogether.

We now have from the almanac (p. 76):

equation of time, Dec. 29, 22^h, G. M. T. $= -2^m\ 26^s.4$,
equation of time, Dec. 30, 0^h, G. M. T. $= -2^m\ 28^s.8$;

and the numbers in this example have been purposely so chosen that the above two tabular values of the equation (between which the required value falls) come from different dates in the almanac. This creates no confusion, for these two values of the equation are really consecutive tabular numbers, just as much as if they occurred on a single date.

The difference between the two values of the equation is

$2^s.4$; and as this difference corresponds to 2^h in the left-hand (or argument) column, it follows that the difference for 1^h is here $1^s.2$. This is the change of the equation per hour of time; it is called the "hourly difference" (abbreviated H. D.) and is printed in the almanac at the foot of each daily column.

Now we want the equation for Dec. 29, $22^h\ 26^m$, by the chronometer. The 26^m must next be changed into a decimal fraction of an hour. $26^m = \frac{26}{60}$ of an hour $= 0^h.43$. So the time for which we want the equation becomes Dec. 29, $22^h.43$. The H. D. being $1^s.2$, the change in $0^h.43$ will be $1^s.2 \times 0.43 = 0^s.5$. The almanac shows that at 22^h the equation was $2^m\ 26^s.4$, and was increasing numerically. Therefore, at $22^h.43$, it was $2^m\ 26^s.4 + 0^s.5 = 2^m\ 26^s.9$. And this number has the *minus* sign. Therefore, the G. M. T. being Dec. 29, $22^h\ 26^m$, the Greenwich apparent time at the same instant will be Dec. 29, $22^h\ 26^m - 2^m\ 26^s.9 =$ Dec. 29, $22^h\ 23^m\ 33^s.1$.

Most of these minor interpolation calculations, which are here set forth in great detail for the benefit of the beginner, can be made with sufficient accuracy by a skilled navigator mentally.

In the foregoing two examples we have assumed that the chronometer was right, but these instruments practically never run quite correctly. Therefore, before leaving port, navigators always have their chronometers "rated" by a chronometer expert; and when the instrument is returned to the ship just before sailing, a "rate card" (or "rate paper") always comes with it. Let us suppose that in the present example this card stated that the chronometer was slow $8^m\ 22^s.5$ [1] on Dec. 20, at noon, and was "losing" [2] $1^s.8$ daily. The $8^m\ 22^s.5$ would then be the "chronometer error" on Dec. 20; and the $1^s.8$ would be its "daily rate."

[1] This number is here purposely chosen much larger than would ever occur in practice.

[2] The opposite kind of "rate" is called "gaining."

From Dec. 20, noon, to Dec. 30, $10^h\ 26^m$ A.M. is an interval of 9 days 22 hours 26 minutes. This interval must now be reduced to a decimal of a day. $26^m = \frac{26}{60}$ of an hour $= 0^h.43$. The interval is therefore $9^d\ 22^h.43$.

But $22^h.43 = \frac{22.43}{24}$ days $= 0^d.93$. Therefore, in days, the interval is $9^d.93$. This transformation of hours and minutes into decimals of a day can be accomplished with less trouble by means of our Table 8 (p. 248).

Having a losing rate of $1^s.8$ daily, the chronometer lost $1^s.8 \times 9.93 = 17^s.9$ in the interval of 9.93 days. And as it was already slow $8^m\ 22^s.5$ on Dec. 20, it was slow $8^m\ 22^s.5 + 17^s.9 = 8^m\ 40^s.4$ at the time for which the equation is required.

Now the equation was required for Dec. 29, $22^h\ 26^m$ by the chronometer; and that instrument being slow $8^m\ 40^s.4$, the correct G. M. T. was: Dec. 29, $22^h\ 26^m + 8^m\ 40^s.4 =$ Dec. 29, $22^h\ 34^m\ 40^s.4$. Turned into a decimal fraction of an hour, this becomes Dec. 29, $22^h.58$, instead of $22^h.43$, as we found before, when the chronometer error was omitted from the calculation. The H. D. is $1^s.2$, as before, and the change in $0^h.58 = 1^s.2 \times 0.58 = 0^s.7$. Therefore, at $22^h.58$ the equation is $2^m\ 26^s.4 + 0^s.7 = 2^m\ 27^s.1$. This still has the *minus* sign, so that the correct Greenwich apparent time becomes Dec. 29, $22^h\ 34^m\ 40^s.4 - 2^m\ 27^s.1 = 22^h\ 32^m\ 13^s.3$.

All the above calculations have been carried out here with unnecessary accuracy. There would be no harm if the result were in error by a few tenths of a second; and it is this circumstance that makes it possible to perform these interpolations largely mentally.

In the foregoing examples no account was taken of the ship's location on the ocean; yet this location may have an indirect influence on the calculations. To understand this, we must consider for a moment the time-differences which exist between different places on the earth. The sun rises in the east and travels across the sky toward the west; so that if we consider two places like Greenwich, England, and New York, for instance, the sun, because of this motion from east

to west, will pass Greenwich first. Consequently, when it is noon in New York, it has already been noon in Greenwich, and is afternoon there. Greenwich time is therefore always later than New York time. The same is true of any other two places; there is always a time-difference between them, and the easterly place has the later or "faster" time.

The amount of such time-difference of course depends on the relative location of the two places, and the relation is such that 15° of longitude-difference corresponds exactly to 1^h of time-difference. Thus Sandy Hook, which is in longitude 73° 50′ west of Greenwich, has a time-difference from Greenwich of $4^h\ 55^m\ 20^s$. This conversion of longitude into time-difference is best accomplished by means of our Table 9 (p. 249). According to that table:

$$\begin{aligned} 73^\circ &= 4^h\ 52^m\ \ 0^s \\ 50' &= \underline{\ \ 3\ \ \ 20} \\ 73^\circ\ 50' &= 4^h\ 55^m\ 20^s \end{aligned}$$

The indirect influence of such time-differences upon the use of the almanac is that they may at times, especially when they are large, make the Greenwich date of the observation different from the date on board. Thus a vessel off Manila Bay, in longitude 120° east of Greenwich, would have her local time 8^h (120°) later than Greenwich time. If a sextant observation was made on board at 4 P.M., civil time, on a Thursday, the chronometer would indicate 8^h, and it would be 8 A.M. on Thursday, because Greenwich is 8^h earlier than the ship. This 8 A.M. would really be 20^h of the preceding Wednesday by astronomic time, and so the almanac date used would be one day earlier than the date of the observation. The chronometer will always give the right Greenwich time, but the navigator must be very careful to interpolate the almanac numbers on the right date.

We have now learned how to ascertain the equation of time from the almanac, and how to use it for transforming G. M. T. into Greenwich apparent time. The contrary transformation, from Greenwich apparent time to G. M. T.,

can be made by applying the equation in the opposite way: subtracting when it has the + sign in the almanac, and adding when it has the − sign.

The great importance of these time transformations comes from the fact that sextant observations must necessarily be made upon the *visible* sun. When they are made for the purpose of calculating the local time on board, this local time will therefore necessarily be local apparent solar time, as kept by the visible sun. At the instant of the observation (p. 6), the chronometer face (corrected for error and rate) tells us the G. M. T. If this is turned into Greenwich apparent time by applying the equation, we have only to compare the Greenwich and the ship's apparent times to get the time-difference between the ship and Greenwich. This time-difference can then be turned into degrees and minutes, and will be the ship's longitude. Examples of this calculation will be given in detail (p. 99). It is also worth noting here that the time-difference between any two places is precisely the same, quite irrespective of the kind of time in which it is counted.

To complete our explanation of the almanac page 29 (our p. 76), it remains to give an example of a calculation of the sun's declination. This is an angle in degrees and minutes, and it is interpolated just like the equation by the aid of its H. D. Thus, for Dec. 29, $22^h.58$ (p. 80) the declination is obtained thus:

Dec. 29, 22^h, declination	$= 23° \; 11'.9$
H.D. $(0'.1) \times 0^h.58$	$=$ 0.1, declination decreasing;
by subtraction, at $22^h.58$, dec.	$= 23° \; 11'.8$,

and according to the almanac, this declination must be given the *minus* sign. When the sign should be +, that fact is indicated in the almanac. The use of the declination will be explained later; the accuracy required in the interpolation of it is not so great as we have used here, for the nearest minute suffices in practically all navigation work.

In addition to the sun's declination, navigators require

in their further calculations another number called the sun's "right ascension" (abbreviated, R. A.). This is obtained from pages like the almanac page 3 (reprinted in part below). It is always the R. A. of the "mean sun" that we need, and the almanac gives it for Greenwich mean noon of each day in the year. When needed in our further calculations, it is of course always required for the exact moment when a sextant observation was made. In fact, this statement applies also to the equation of time and declination. They must always be interpolated from the almanac for the moment when the navigator actually observed the sun; and

SUN, 1917. *From* Nautical Almanac, p. 3

Day of Month	Right Ascension of the Mean Sun at Greenwich Mean Noon																	
	July			August			September			October			November			December		
	h	m	s	h	m	s	h	m	s	h	m	s	h	m	s	h	m	s
1	6	35	52.2	8	38	5.5	10	40	18.7	12	38	35.3	14	40	48.4	16	39	5.1
2	6	39	48.8	8	42	2.0	10	44	15.2	12	42	31.8	14	44	45.0	16	43	1.7
3	6	43	45.3	8	45	58.6	10	48	11.8	12	46	28.4	14	48	41.5	16	46	58.2
4	6	47	41.9	8	49	55.1	10	52	8.3	12	50	24.9	14	52	38.1	16	50	54.8
5	6	51	38.4	8	53	51.7	10	56	4.9	12	54	21.5	14	56	34.6	16	54	51.3
6	6	55	35.0	8	57	48.2	11	0	1.4	12	58	18.0	15	0	31.2	16	58	47.9
7	6	59	31.6	9	1	44.8	11	3	58.0	13	2	14.6	15	4	27.8	17	2	44.5
8	7	3	28.1	9	5	41.4	11	7	54.5	13	6	11.1	15	8	24.3	17	6	41.0
9	7	7	24.7	9	9	37.9	11	11	51.1	13	10	7.7	15	12	20.9	17	10	37.6
10	7	11	21.2	9	13	34.5	11	15	47.6	13	14	4.2	15	16	17.4	17	14	34.1
11	7	15	17.8	9	17	31.0	11	19	44.2	13	18	0.8	15	20	14.0	17	18	30.7
12	7	19	14.3	9	21	27.6	11	23	40.8	13	21	57.3	15	24	10.5	17	22	27.2
13	7	23	10.9	9	25	24.1	11	27	37.3	13	25	53.9	15	28	7.1	17	26	23.8
14	7	27	7.4	9	29	20.7	11	31	33.9	13	29	50.4	15	32	3.6	17	30	20.4
15	7	31	4.0	9	33	17.2	11	35	30.4	13	33	47.0	15	36	0.2	17	34	16.9
16	7	35	0.6	9	37	13.8	11	39	27.0	13	37	43.6	15	39	56.8	17	38	13.5
17	7	38	57.1	9	41	10.4	11	43	23.5	13	41	40.1	15	43	53.3	17	42	10.0
18	7	42	53.7	9	45	6.9	11	47	20.1	13	45	36.7	15	47	49.9	17	46	6.6
19	7	46	50.2	9	49	3.5	11	51	16.6	13	49	33.2	15	51	46.4	17	50	3.2
20	7	50	46.8	9	53	0.0	11	55	13.2	13	53	29.8	15	55	43.0	17	53	59.7
21	7	54	43.4	9	56	56.6	11	59	9.7	13	57	26.3	15	59	39.5	17	57	56.3
22	7	58	39.9	10	0	53.1	12	3	6.3	14	1	22.9	16	3	36.1	18	1	52.8
23	8	2	36.5	10	4	49.7	12	7	2.8	14	5	19.4	16	7	32.6	18	5	49.4
24	8	6	33.0	10	8	46.2	12	10	59.4	14	9	16.0	16	11	29.2	18	9	46.0
25	8	10	29.6	10	12	42.8	12	14	55.9	14	13	12.5	16	15	25.8	18	13	42.5
26	8	14	26.1	10	16	39.4	12	18	52.5	14	17	9.1	16	19	22.3	18	17	39.1
27	8	18	22.7	10	20	35.9	12	22	49.0	14	21	5.6	16	23	18.9	18	21	35.6
28	8	22	19.2	10	24	32.4	12	26	45.6	14	25	2.2	16	27	15.4	18	25	32.2
29	8	26	15.8	10	28	29.0	12	30	42.2	14	28	58.8	16	31	12.0	18	29	28.7
30	8	30	12.4	10	32	25.6	12	34	38.7	14	32	55.3	16	35	8.6	18	33	25.3
31	8	34	8.9	10	36	22.1	12	38	35.3	14	36	51.9	16	39	5.1	18	37	21.9

CORRECTION TO BE ADDED TO R. A. M. S. AT G. M. N. FOR TIME PAST NOON

From Nautical Almanac, p. 3, *Continued*

TIME	0^m	6^m	12^m	18^m	24^m	30^m	36^m	42^m	48^m	TIME
h	m s	m s	m s	m s	m s	m s	m s	m s	m s	h
12	1 58.3	1 59.3	2 0.2	2 1.2	2 2.2	2 3.2	2 4.2	2 5.2	2 6.2	12
13	2 8.1	2 9.1	2 10.1	2 11.1	2 12.1	2 13.1	2 14.0	2 15.0	2 16.0	13
14	2 18.0	2 19.0	2 20.0	2 20.9	2 21.9	2 22.9	2 23.9	2 24.9	2 25.9	14
15	2 27.8	2 28.8	2 29.8	2 30.8	2 31.8	2 32.8	2 33.8	2 34.7	2 35.7	15
16	2 37.7	2 38.7	2 39.7	2 40.7	2 41.6	2 42.6	2 43.6	2 44.6	2 45.6	16
17	2 47.6	2 48.5	2 49.5	2 50.5	2 51.5	2 52.5	2 53.5	2 54.5	2 55.4	17
18	2 57.4	2 58.4	2 59.4	3 0.4	3 1.4	3 2.3	3 3.3	3 4.3	3 5.3	18
19	3 7.3	3 8.3	3 9.2	3 10.2	3 11.2	3 12.2	3 13.2	3 14.2	3 15.2	19
20	3 17.1	3 18.1	3 19.1	3 20.1	3 21.1	3 22.1	3 23.0	3 24.0	3 25.0	20
21	3 27.0	3 28.0	3 29.0	3 29.9	3 30.9	3 31.9	3 32.9	3 33.9	3 34.9	21
22	3 36.8	3 37.8	3 38.8	3 39.8	3 40.8	3 41.8	3 42.8	3 43.7	3 44.7	22
23	3 46.7	3 47.7	3 48.7	3 49.7	3 50.6	3 51.6	3 52.6	3 53.6	3 54.6	23

the Greenwich time of this event is of course always taken from the chronometer (duly corrected for error and rate).

Thus, if the R. A. of the mean sun is required for Dec. 29, $22^h\ 34^m\ 40^s.4$, G. M. T. (p. 80), we find from the almanac page 3 (our p. 83) that the R. A. of the mean sun at Greenwich mean noon is $18^h\ 29^m\ 28^s.7$.[1] This, according to the supplementary table quoted above from page 3, must be increased by a correction for "time past noon." In this case the time past noon is $22^h\ 34^m\ 40^s.4$. The tabular correction for $22^h\ 30^m$ is $3^m\ 41^s.8$, and for $22^h\ 36^m$ it is $3^m\ 42^s.8$. Ours falls between these two, and an interpolation makes the correction $3^m\ 42^s.6$. Consequently, the R. A. of the mean sun for Dec. 29, $22^h\ 34^m\ 40^s.4$, G. M. T. is $18^h\ 29^m\ 28^s.7 + 3^m\ 42^s.6 = 18^h\ 33^m\ 11^s.3$.

It will be noticed that the small supplementary table (quoted above from almanac page 3) only runs from 12^h to 24^h. The other half of the table, from 0^h to 12^h, is printed on the opposite page 2 of the almanac. There is also another longer table, printed near the end of the almanac, and there called Table III, from which the supplementary correction can be taken without the necessity of interpolation.

It is not absolutely essential that the navigator learn what

[1] Right ascensions are always thus measured in hours, minutes, and seconds, like time, and they are counted from 0^h to 24^h.

the words "right ascension" and "declination" really mean. But for the benefit of those who are curious in such matters we may state that these numbers locate the position of the sun (or of a star) on the sky. The sky is a great globe, called by astronomers the "celestial sphere," and all heavenly bodies are located upon it precisely as points on the earth are there located by their latitudes and longitudes (p. 3). There is a "celestial equator" with two "celestial poles," corresponding accurately to the terrestrial equator and poles. Declination then corresponds exactly to latitude on the earth, and so it measures the distance of a heavenly body from the celestial equator. When the body is north of the celestial equator, the declination is called +.

Right ascension similarly corresponds to longitude; and for the beginning point of right ascensions on the sky there is a "celestial Greenwich," which is called the "vernal equinox."

After this brief digression into astronomy, we return to our subject. We have seen (p. 82) that observations of the sun will tell us only apparent solar time, because it is only the visible sun that we can observe. If the observations are made upon a star, the kind of time is different from any so far mentioned. It is called "sidereal time," or star time.

It is always possible to change mean solar time into sidereal time, and *vice versa*, by a simple process of calculation; but the only change of this kind required in navigation is the transformation of G. M. T. into Greenwich sidereal time. To make this transformation, we have only to take from the almanac, for the given G. M. T., the R. A. of the mean sun, and then to add it to the given G. M. T.

Thus, to find the Greenwich sidereal time corresponding to Dec. 29, $22^h\ 34^m\ 40^s.4$, G. M. T., we have already found

(p. 84) that the R. A. of the mean sun	$= 18^h\ 33^m\ 11^s.3$
To this must be added the given G. M. T.	$= 22\ \ 34\ \ 40.4$
Sum = corresponding Greenwich sidereal time	$= 17^h$[1] $7^m\ 51^s.7$

[1] The number of hours was here really 41^h: but whenever it is larger than 24^h, we must drop or reject 24^h.

CHAPTER VIII

OLDER NAVIGATION METHODS

We shall now explain in detail certain standard methods of determining a ship's latitude and longitude by means of sextant observations. An understanding of these methods is essential to a proper comprehension of the newer navigational processes to be described later; and the older methods are in fact still very widely used at sea, although most recent authorities believe they should be rejected in favor of the newer procedure.

The simplest of these older processes, and the one most frequently employed, is the determination of the ship's latitude by a noon or "meridian" observation ("noon-sight") of the sun's altitude (p. 61). Now the sun is higher in the sky at noon than it is at any other time during the day; and so it is possible to get the noon-sight by beginning to observe the sun with the sextant a few minutes before noon, and continuing the observation as long as the sun's altitude is increasing. The moment it begins to diminish, or the sun to "dip," as sailors say, the observation should be terminated, and the vernier read.

The altitude thus observed will be an altitude of the lower limb (p. 71); and before it is used further it must be fully corrected for index error; for refraction parallax and semi-diameter; and for dip; all as in the example on p. 73, where the observed altitude was 30° 28′, and we found the corrected altitude to be 30° 38′.

Next, the sun's declination must be taken from the almanac, being interpolated for the Greenwich time of the

observation, as in the example on p. 82, where we found the declination to be $-23° 12'$ on Dec. 29, at $22^h\ 34^m\ 40^s.4$, G. M. T. We shall suppose the above altitude $30° 28'$ to have been observed at the Greenwich time stated, so as to make use of the results of our former calculated examples. Nor is there any inconsistency in supposing a noon observation to have been made at $22^h\ 34^m\ 40^s.4$. For the noon observation is made when it is noon on board ship, while the $22^h\ 34^m\ 40^s.4$ is the G. M. T. at the same moment. The difference is simply the time-difference (p. 80) between Greenwich and the ship.

The calculation of the ship's latitude is now made by the following formula:

$$\text{Latitude} = 90° + \text{Declination} - \text{Altitude}.$$

In this formula, the *plus* sign signifies that the declination must be *added;* and the *minus* sign signifies that the altitude must be *subtracted.* Furthermore, it is most important to remember that if the declination is itself a "*minus* declination," as in this example, the addition of it according to the formula is really a subtraction. Or, in other words, and in general, whenever a formula calls for an addition, and the number to be added is a *minus* number, then that number must be subtracted instead of added. And similarly, if the formula calls for a subtraction, and the number to be subtracted is a *minus* number, then that number must be added instead of subtracted. Two *minus* signs neutralize each other.

In the present case we have, omitting seconds:

		90° 0′
declination	=	−23 12
90° + declination	=	66 48
altitude	=	30 38
latitude	=	36 10

In considering this result it is of interest to inquire where this observation really locates the ship. Now we have not yet stated what the date was, on board, when the observa-

tion was made; but we have given the G. M. T. as Dec. 29, $22^h\ 34^m\ 40^s.4$. The noon-sight was taken, as a matter of fact, at noon on Dec. 30, or at the moment when the date Dec. 30 commenced by astronomic reckoning. Therefore the ship's time was later than the Greenwich time by about $1^h\ 25^m$; or 21° 15′, allowing 15° to 1^h (p. 81); and the ship was (approximately) in 21° 15′ east longitude from Greenwich. This, together with the latitude 36° 10′, locates the ship in the Mediterranean, south of Greece, and west of Candia.

Although we have thus apparently located the ship completely in latitude and longitude from a single noon-sight, it must not be supposed that we have really accomplished this. The noon-sight is only suitable for ascertaining the ship's latitude; the longitude is determined so inaccurately as to be practically useless. The reason for this is that near noon the sun changes its altitude very slowly, because it is then near the turning-point where its upward morning motion is about to become a downward afternoon motion. For the sun's daily motion in the sky is upward in the morning and downward in the afternoon. Near noon it runs along horizontally, or very nearly so, for several minutes, so that its altitude change is insignificant during that time.

It follows from this temporary invariability of altitude that we cannot determine the exact moment when noon occurs by observing altitude changes with the sextant. But the latitude determination is not affected; because, for the latitude, we only need to know the noon altitude. And if we happen to measure it a little too soon or too late, on account of the difficulty of fixing the moment of noon, no harm will result, because the altitude very near noon is the same as it is at noon precisely, as we have just seen.

It is, in general, practically impossible to determine *both* latitude and longitude from a single observation. To determine *two* unknown things, at least two different observations must be made. Nor can any skillful method of planning the observation overcome this fundamental circumstance.

Returning now to our latitude formula (p. 87), it is necessary to modify it somewhat in case we happen to be in the tropics, where the sun may pass between the zenith and the celestial pole. Even in temperate latitudes a celestial body may do this, if we happen to observe a star instead of the sun. In such a case, if the ship is in the northern hemisphere, the navigator will observe the sun's altitude toward the north at noon instead of toward the south, as usual. Furthermore, in very high northern latitudes, the "midnight sun," as it is called, can be observed toward the north, and *below* the celestial pole. This is the minimum altitude during the day, instead of the maximum; but it is usable for a latitude determination. Such an observation is called a "lower transit"; and it can often be observed in the case of stars in temperate latitudes.

If we now remember to call northerly latitudes and declinations *plus*, and southerly ones *minus*, we have the following complete set of formulas for the present problem, including observations in both hemispheres. These formulas are so arranged that we can easily choose the right formula, by having regard to the + and − signs. But the right formula *once chosen*, the latitude is calculated without marking declinations with either the + or − sign.

lat.[1] and dec. both + or both −	if lat. greater than dec.,	lat. = 90° + dec. − alt.	(1)
	if dec. greater than lat.,	lat. = dec. + alt. − 90°	(2)
	if lower transit,	lat. = 90° + alt. − dec.	(3)
lat. and dec., one +, one −		lat. = 90° − alt. − dec.	(4)

We shall now give some more examples; and to enable the reader to follow star observations correctly we reprint part of the upper halves of pages 94 and 95 (our pp. 91, 92) of the Nautical Almanac. These contain the right ascensions and declinations (p. 85) of a quantity of bright stars for various dates in the year. These numbers are correct for the moment of "upper transit," which is the moment when these

[1] Latitude and declination are abbreviated lat. and dec.

stars attain their maximum altitudes. This event cannot be called a noon-sight in the case of a star; but it is observable in a manner perfectly similar to a solar noon-sight.

These stellar right ascensions and declinations change so slowly that it is unnecessary to use interpolation when taking them from the almanac pages.

Proceeding now to our examples, suppose that on shore, at Sandy Hook Light, approximate latitude and longitude 40° 28′ N., 74° 0′ W., on Monday, Dec. 17, 1917, at noon, the double altitude of the sun's lower limb was observed with a sextant and artificial horizon, and found to be 51° 48′. The index correction required by the sextant was + 4′; and the G. M. T. by chronometer was 4^h 56^m at the moment the observation was made. Find the latitude. We have:

Observed double altitude	51°	48′	(1)
Index correction		+ 4	(2)
Adding (1) and (2) gives corrected double altitude	51°	52′	(3)
Halving (3) gives observed altitude	25	56	(4)
Correction from Table 6[1] (p. 247)	+	14	(5)
Adding (4) and (5) gives fully corrected altitude	26°	10′	(6)
Now use formula (4) (p. 89) because latitude is + and declination is −. Write	90	0	(7)
Subtracting (6) from (7) gives 90° − corrected altitude . .	63	50	(8)
Interpolate declination from almanac (p. 76). This gives declination	23	22	(9)
Subtracting (9) from (8) gives for the latitude	40	28	(10)

With regard to the foregoing example it is worth remarking that if there had been no available chronometer set to Greenwich time, it would still have been possible to calculate the observation. For the known approximate longitude, even if only a dead-reckoning (p. 5) longitude, would be quite accurate enough to make possible the interpolation of the declination from the almanac. And in the present example, the chronometer was only used in getting the declination printed in line (9) above.

[1] Dip correction from Table 7 not needed because the artificial horizon was used.

APPARENT PLACES OF STARS, 1917

From Nautical Almanac, p. 94

For the Upper Transit at Greenwich

No.	Constellation Name	Right Ascension										
			Jan. 1	May 1	June 1	July 1	Aug. 1	Sept. 1	Oct. 1	Nov. 1	Dec. 1	Dec. 32
		h m	s	s	s	s	s	s	s	s	s	s
1	α Androm.	0 4	6.3	6.4	7.4	8.4	9.4	10.0	10.3	10.3	10.0	9.6
2	β Cassiop.	0 4	44.8	44.4	45.7	47.3	48.7	49.7	50.1	49.9	49.3	48.4
3	β Ceti	0 39	26.5	26.3	27.0	28.0	28.9	29.7	30.0	30.1	29.8	29.5
4	δ Cassiop.	1 20	23.9	22.3	23.5	25.1	26.7	28.1	28.9	29.2	29.0	28.2
5	α Urs. Min.	1 29	89.0	22.9	45.5	77.6	112.8	142.4	161.2	166.4	155.3	129.0
6	α Eridani	1 34	39.1	36.8	37.6	38.8	40.3	41.5	42.3	42.4	41.9	41.1
7	α Arietis	2 2	31.0	30.1	30.8	31.7	32.7	33.6	34.3	34.6	34.7	34.5
8	θ Eridani	2 55	8.8	6.8	7.2	7.9	9.0	10.0	10.8	11.3	11.4	11.0
9	α Persei	3 18	25.9	23.9	24.4	25.5	26.8	28.2	29.3	30.2	30.6	30.5
10	α Tauri	4 31	11.7	10.3	10.5	11.0	11.9	12.8	13.7	14.5	15.0	15.2
11	β Orionis	5 10	35.1	33.7	33.7	34.2	34.7	35.6	36.5	37.3	37.8	38.1
12	α Aurigæ	5 10	36.5	34.5	34.6	35.2	36.2	37.5	38.7	39.9	40.7	41.1
13	γ Orionis	5 20	43.1	41.7	41.7	42.1	42.8	43.7	44.6	45.4	46.0	46.4
14	ε Orionis	5 32	2.4	1.0	1.0	1.3	2.0	2.8	3.7	4.5	5.2	5.5
15	α Orionis	5 50	43.1	41.8	41.7	42.0	42.7	43.5	44.4	45.3	46.0	46.4
16	α Argus	6 22	9.2	6.1	5.5	5.4	6.0	6.9	8.1	9.3	10.2	10.6
17	α Can. Maj.	6 41	31.6	30.2	30.0	30.1	30.6	31.3	32.2	33.1	33.8	34.3
18	ε Can. Maj.	6 55	24.1	22.6	22.2	22.2	22.6	23.3	24.2	25.2	26.0	26.5
19	α Can. Min.	7 34	59.7	59.0	58.7	58.8	59.1	59.8	60.5	61.5	62.3	63.0
20	β Gemin.	7 40	17.1	16.3	16.0	16.0	16.4	17.1	18.0	19.0	20.0	20.8
21	ε Argus	8 20	51.4	49.0	48.0	47.3	47.2	47.8	48.9	50.4	51.8	52.8
22	λ Argus	9 4	58.6	57.9	57.3	56.9	56.8	57.1	57.8	58.9	60.1	61.0
23	β Argus	9 12	20.6	18.1	16.4	15.1	14.5	14.8	16.0	17.9	20.0	21.7
24	α Hydræ	9 23	32.5	32.6	32.2	32.0	32.0	32.3	32.9	33.7	34.7	35.6
25	α Leonis	10 3	59.2	59.7	59.3	59.1	59.0	59.2	59.7	60.5	61.4	62.4

Had it been thus necessary to get the declination without using the chronometer, we should have proceeded as follows:

Apparent solar time of noon (p. 75)	0^h 0^m	(1)
Approximate longitude = 74° 0′ W. = (at 15° to the hour)	4 56 W.	(2)
Adding (1) and (2) (p. 81) gives approximate Greenwich apparent time.	4 56	(3)
Approx. eq. of time, Dec. 17, at 4^h 56^m (p. 76)	+ 4	(4)
Subtracting[1] (4) from (3) gives approximate G. M. T.	4 52	(5)
Declination interpolated for G. M. T. in line (5) is	− 23° 22′	(6)

[1] The equation is additive to G. M. T., according to the note at the foot of p. 76, and therefore to be subtracted from Greenwich apparent time.

APPARENT PLACES OF STARS, 1917

From Nautical Almanac, p. 95

FOR THE UPPER TRANSIT AT GREENWICH

No.	Declination										Special Name	Mag.[1]
		Jan. 1	Feb. 1	Mar. 1	Apr. 1	May 1	Oct. 1	Nov. 1	Dec. 1	Dec. 32		
	°	′	′	′	′	′	′	′	′	′		
1	+ 28	38.2	38.1	38.0	38.0	38.0	38.4	38.5	38.5	38.5	Alpheratz	2.2
2	+ 58	41.9	41.8	41.7	41.6	41.5	42.0	42.1	42.2	42.2	Caph	2.4
3	− 18	26.5	26.5	26.5	26.4	26.3	26.0	26.1	26.2	26.2	Deneb Kaitos	2.2
4	+ 59	48.7	48.7	48.6	48.4	48.3	48.6	48.8	48.9	49.0	Ruchbah	2.8
5	+ 88	52.2	52.2	52.1	52.0	51.8	52.0	52.2	52.4	52.5	Polaris	2.1
6	− 57	39.7	39.7	39.6	39.4	39.2	39.0	39.2	39.3	39.4	Achernar	0.6
7	+ 23	4.5	4.4	4.4	4.3	4.3	4.6	4.7	4.7	4.7	Hamal	2.2
8	− 40	38.3	38.3	38.3	38.2	38.1	37.7	37.8	38.0	38.1	Acamar	3.0
9	+ 49	34.3	34.3	34.3	34.2	34.1	34.3	34.3	34.4	34.5		1.9
10	+ 16	20.7	20.7	20.7	20.7	20.7	20.8	20.8	20.8	20.8	Aldebaran	1.1
11	− 8	17.8	17.8	17.9	17.9	17.8	17.5	17.6	17.7	17.7	Rigel	0.3
12	+ 45	55.0	55.1	55.1	55.1	55.0	54.9	54.9	55.0	55.1	Capella	0.2
13	+ 6	16.6	16.5	16.5	16.5	16.5	16.7	16.7	16.6	16.6	Bellatrix	1.7
14	− 1	15.2	15.3	15.3	15.3	15.3	15.0	15.1	15.1	15.2	Alnitam	1.8
15	+ 7	23.6	23.5	23.5	23.5	23.5	23.7	23.7	23.6	23.6	Betelgeux	1.0–1.4
16	− 52	39.0	39.2	39.3	39.3	39.2	38.7	38.7	38.9	39.1	Canopus	− 0.9
17	− 16	36.1	36.2	36.3	36.3	36.3	35.9	36.0	36.1	36.2	Sirius	− 1.6
18	− 28	51.5	51.7	51.7	51.8	51.7	51.3	51.4	51.5	51.6	Adhara	1.6
19	+ 5	26.3	26.2	26.2	26.2	26.2	26.3	26.2	26.2	26.1	Procyon	0.5
20	+ 28	13.6	13.6	13.6	13.7	13.7	13.5	13.5	13.4	13.4	Pollux	1.2
21	− 59	14.4	14.6	14.8	14.9	14.9	14.4	14.4	14.5	14.7		1.7
22	− 43	5.7	5.9	6.1	6.2	6.2	5.8	5.8	5.9	6.0		2.2
23	− 69	22.4	22.6	22.8	22.9	23.0	22.5	22.4	22.5	22.7	Miaplacidus	1.8
24	− 8	17.9	18.1	18.1	18.2	18.2	18.0	18.0	18.1	18.2	Alphard	2.2
25	+ 12	22.2	22.2	22.2	22.2	22.2	22.2	22.1	22.0	21.9	Regulus	1.3

[1] When the number in this column is very small, and especially when it is *minus*, the star is very bright.

It is further to be noted that as we can thus obtain the approximate G. M. T., we really know in advance the approximate moment when the observation should be made. So it is unnecessary to get the sextant ready a long time before the observation; and it is, in fact, better to observe at the proper predetermined approximate moment rather than to wait for the maximum altitude (p. 86).

When the ship's position at noon can be predicted with fair approximation, it is thus possible to have the declination and other numbers for calculating the noon-sight also all ready

in advance, so that the latitude will be immediately available when the noon altitude has been read from the sextant.

We shall now consider the following example: Off St. Paul de Loando, West Africa, approximate latitude 8° 55′ south, approximate longitude 12° 55′ east, both predicted in advance by D. R. for noon on Monday, Dec. 31. The altitude of the sun's lower limb is to be measured. Index correction is − 5′. Height of eye, 26 ft.

To prepare for the observation, we have, as before:

Apparent solar time of noon	0^h	0^m	(1)
Approximate D. R. longitude = 12° 55′ east = (at 15° to the hour)		52 E.	(2)
Subtracting (2) from (1) gives approximate Greenwich apparent time, Dec. 30	23	8	(3)
Approximate equation of time, Dec. 30, at 23^h 8^m (p. 76)	−	3	(4)
Subtracting (4) from (3), having regard to − sign of (4), gives approximate G. M. T.	23	11	(5)

The navigator will then make the observation when the G. M. T. is 23^h 11^m, as indicated by the chronometer, duly corrected for error and rate. This would of course also be noon, or the time when the sun attained its maximum altitude for the day.

Now the dials of chronometers are always divided into 12 hours, like ordinary watches, although navigators count time through 24 hours, as we have seen (p. 75). The reason is that the dial would be overloaded with numbers if there were 24 hour divisions. Therefore, when we speak of the chronometer indicating 23^h 11^m, it must be understood that the actual chronometer indication, or "chronometer face," as it is sometimes called, would really be 11^h 11^m; only, the navigator would call it 23^h 11^m, astronomic time. In this manner civil time still forces its way into navigation, by way of the chronometer face.

To make the observation at the prearranged G. M. T. by chronometer it is not desirable to carry that instrument out into the sunlight, where the observer stands. It is much

better for the navigator to use his watch, and to calculate in advance the "watch time" of the observation. To do this, it is merely necessary to compare the watch with the chronometer, and thus ascertain how much the watch is slow or fast of the chronometer. This amount is called "chronometer *minus* watch" (abbreviated C. – W.); and when the watch is fast of the chronometer, C. – W. is marked with the *minus* sign.

To obtain the watch time for the observation, we subtract C. – W. from the G. M. T. In the present case we will suppose the watch was 47^m fast of the chronometer. Then C. – W. = -47^m. To get the watch time for the observation we must subtract -47^m from $23^h\ 11^m$. Subtracting a minus number is equivalent to addition; and so the watch time is $23^h\ 11^m + 47^m = 23^h\ 58^m$. The observation would be made as nearly as possible 2^m before noon, by the watch.

In this connection it also becomes of interest to inquire how the navigator's watch happened to be 47^m fast of the chronometer. It is customary aboard ship to set the deck and cabin clocks, and all watches, to the ship's local apparent time once a day at least. To do this, we proceed as follows:

Take from chronometer the G. M. T., corrected for error and rate (1)
Apply to this G. M. T. the eq. of time, giving Green'h app. time (2)
Apply to (2) the approximate D. R. longitude, adding it if longitude is E., which gives ship's apparent time............. (3)
And set the watch to the time (3).

An example of this proceeding can be had from the data on p. 93. Suppose the watch was to be set; and the chronometer time was $23^h\ 0^m$. We should then prepare to set the watch in about 5^m, when the

G. M. T. by chronometer would be...............	23^h	5^m	(1)
Chronometer error (corrected for rate) say.........		-2	(2)
Corrected G. M. T. by chronometer, (1) + (2).......	23	3	(3)
Equation of time (p. 93).......................		-3	(4)
Greenwich apparent time, (3) + (4)...............	23	0	(5)
Approximate longitude (p. 93).....................		52 E.	(6)
Ship's apparent time, (5) + (6)....................	23	52	(7)

And the watch would be set to $23^h\ 52^m$, when the chronometer face was $23^h\ 5^m$; or, which is the same thing, the watch would be set at 8^m to 12 when the chronometer indicated 5 minutes past 11.

Sometimes the navigator wishes the watch to be correct by ship's apparent time at noon, but desires to set it right half an hour sooner, so as to be free at noon to make an observation. In that case he calculates by D. R. what the longitude will be at noon, and proceeds practically in the same way as before.

Resuming now the example of p. 93, we are still off St. Paul de Loando, and at 2^m before noon by the watch (p. 94) the altitude of the sun's lower limb was measured.

Suppose it was found to be	75°	34′	(1)
The index correction was		− 5	(2)
Adding (1) and (2), with regard to sign of (2), gives corrected altitude	75	29	(3)
Correction from Table 6		+ 16	(4)
Correction from Table 7, for 26 ft. height of eye		− 5	(5)
Adding (3), (4), (5) gives corrected altitude	75	40	(6)
Formula (2), p. 89, is the proper one, and the interpolated declination, disregarding sign, is	23	8	(7)
Latitude, by formula, is (6) + (7) − 90°, or	8	48	(8)

The latitude of the ship is therefore 8° 48′ south, from the above noon-sight observation. The difference of 7′ from the approximate latitude (p. 93) might easily be caused by ocean currents.

Our next example is a star observation. Position of ship by D. R. March 23, 1917, at $6^h\ 30^m$ ship's time is: latitude 40° 25′ N., longitude 46° 52′ W., so that she is near the turning point in the southern "lane route" followed by steamships bound from New York to Fastnet in summer. The upper transit (p. 89) of Sirius was observed; and the sextant altitude was 33° 7′. Index correction, − 7′; height of eye, 24 ft.

The calculation is as follows:

Observed altitude of Sirius	33°	7′	(1)
Index correction		− 7	(2)
Adding (1) and (2), having regard to *minus* sign of (2), gives corrected altitude	33	0	(3)
Correction Tables 6 and 7, combined		− 6	(4)
Adding (3) and (4) gives finally corrected altitude	32	54	(5)
Use formula (4), p. 89, because latitude is + and declination of Sirius −. We have	90°		(6)
Subtract (5) from (6), giving (90° − altitude)	57	6	(7)
Declination of Sirius (p. 92), disregarding sign, is	16	36	(8)
Subtract (8) from (7), giving (90° − altitude − declination), or the latitude	40	30	(9)

Ship's latitude at the moment of observation was therefore 40° 30′ N.

In making such a star observation, it is of course possible to follow the star with the sextant until it begins to dip (p. 86) toward the horizon exactly as we have explained for the sun. But it is preferable to prepare for the observation in advance, and to make it at a definite predetermined minute by the navigator's watch. To make such preparation, it is necessary to use pages 96 and 97 of the Nautical Almanac, parts of which pages are reprinted here (pp. 97, 98).

The almanac page 96 gives for all the bright stars the G. M. T. of upper transit (p. 89) at Greenwich, for the first day of each month. And it will be noticed that the upper transit is here called "meridian transit," which is practically another name for the same thing. Almanac page 97 (our p. 98) then gives a subtractive correction, applicable to the numbers on page 96, to make them correct on days of the month other than the 1st.

Another small correction is still required to make the numbers right in the approximate D. R. longitude of the ship, instead of the longitude of Greenwich, as used on almanac page 96. This correction is subtractive, if the ship is in west longitude, and additive, if she is in east longitude; and the

MERIDIAN TRANSIT OF STARS, 1917

From Nautical Almanac, p. 96

GREENWICH MEAN TIME OF TRANSIT AT GREENWICH

CONSTELLATION NAME	MAG.	JAN. 1	FEB. 1	MAR. 1	APR. 1	MAY 1	SEPT. 1	OCT. 1	NOV. 1	DEC. 1
		h m	h m	h m	h m	h m	h m	h m	h m	h m
α Androm.	2.2	5 21	3 19	1 29	23 23	21 25	13 22	11 24	9 22	7 24
β Cassiop.	2.4	5 22	3 20	1 30	23 24	21 26	13 22	11 24	9 22	7 24
β Ceti	2.2	5 56	3 54	2 4	{0 2 / 23 58}	22 0	13 57	11 59	9 57	7 59
δ Cassiop.	2.8	6 37	4 35	2 45	0 43	22 41	14 38	12 40	10 38	8 40
α Urs. Min.	2.1	6 47	4 45	2 54	0 52	22 50	14 49	12 51	10 49	8 51
α Eridani	0.6	6 51	4 49	2 59	0 57	22 55	14 52	12 54	10 52	8 54
α Arietis	2.2	7 19	5 17	3 27	1 25	23 23	15 20	13 22	11 20	9 22
θ Eridani	3.0	8 12	6 10	4 20	2 18	0 20	16 12	14 14	12 12	10 14
α Persei	1.9	8 35	6 33	4 43	2 41	0 43	16 35	14 38	12 36	10 38
α Tauri	1.1	9 47	7 46	5 55	3 54	1 56	17 48	15 50	13 48	11 50
β Orionis	0.3	10 27	8 25	6 35	4 33	2 35	18 27	16 29	14 28	12 30
α Aurigæ	0.2	10 27	8 25	6 35	4 33	2 35	18 27	16 29	14 28	12 30
γ Orionis	1.7	10 37	8 35	6 45	4 43	2 45	18 37	16 39	14 38	12 40
ε Orionis	1.8	10 48	8 46	6 56	4 54	2 56	18 49	16 51	14 49	12 51
α Orionis	1.0–1.4	11 7	9 5	7 15	5 13	3 15	19 7	17 9	15 7	13 9
α Argus	– 0.9	11 38	9 36	7 46	5 44	3 46	19 39	17 41	15 39	13 41
α Can. Maj.	– 1.6	11 57	9 55	8 5	6 3	4 5	19 58	18 0	15 58	14 0
ε Can. Maj.	1.6	12 11	10 9	8 19	6 17	4 19	20 12	18 14	16 12	14 14
α Can. Min.	0.5	12 51	10 49	8 59	6 57	4 59	20 51	18 53	16 52	14 54
β Gemin.	1.2	12 56	10 54	9 4	7 2	5 4	20 57	18 59	16 57	14 59
ε Argus	1.7	13 36	11 34	9 44	7 42	5 44	21 37	19 39	17 37	15 39
λ Argus	2.2	14 20	12 19	10 28	8 27	6 28	22 21	20 23	18 21	16 23
β Argus	1.8	14 28	12 26	10 36	8 34	6 36	22 28	20 30	18 28	16 31
α Hydræ	2.2	14 39	12 37	10 47	8 45	6 47	22 40	20 42	18 40	16 42
α Leonis	1.3	15 19	13 17	11 27	9 25	7 27	23 20	21 22	19 20	17 22

amount of it is 10^s for every 15° in the ship's longitude. After it has been applied, the result will be the ship's mean solar time of the star's upper transit.

As an example, let us take the preparation for the foregoing observation of Sirius, or α Can. Maj. We have:

G. M. T. of upper transit, March 1, from almanac page 96 above	8^h	5^m	(1)
Correction for 23d day of month, from almanac page 97 (our p. 98)	– 1	27	(2)
Correcting (1) with (2), having regard to – sign of (2)	6	38	(3)
Further correction for longitude 46° 52′ W., at 10^s per 15° of longitude, approximately		1	(4)
Subtracting (4) from (3) gives ship's mean solar time of the observation	6	37	(5)

MERIDIAN TRANSIT OF STARS, 1917

From Nautical Almanac, p. 97

CORRECTIONS TO BE APPLIED TO THE MEAN TIME OF TRANSIT ON THE FIRST DAY OF THE MONTH, TO FIND THE MEAN TIME OF TRANSIT ON ANY OTHER DAY OF THE MONTH

Day of Month	Correction	Day of Month	Correction	Day of Month	Correction
	h m		h m		h m
1	−0 0	11	−0 39	21	−1 19
2	0 4	12	0 43	22	1 23
3	0 8	13	0 47	23	1 27
4	0 12	14	0 51	24	1 30
5	0 16	15	0 55	25	1 34
6	−0 20	16	−0 59	26	−1 38
7	0 24	17	1 3	27	1 42
8	0 28	18	1 7	28	1 46
9	0 31	19	1 11	29	1 50
10	0 35	20	1 15	30	1 54
11	−0 39	21	−1 19	31	−1 58

NOTE. If the quantity taken from this Table is greater than the mean time of transit on the first of the month, increase that time by $23^h\ 56^m$ and then apply the correction taken from this Table.

The actual observation was made at $6^h\ 30^m$, ship's time, as indicated by the navigator's watch. The difference of 7^m between $6^h\ 30^m$, and $6^h\ 37^m$ in line (5) above, is due to the equation of time (p. 77), which is 7^m on March 23. This 7^m, if applied (with its proper sign from the almanac) to line (5) above, will give the ship's apparent time; and we have seen that watches and clocks on board are usually kept set to apparent and not mean ship's time (p. 94).

To complete this part of our subject, we have still to consider a few additional points of interest. For instance, a star chosen for observation may be one of the planets: Mars, Jupiter, or Saturn. These look like *very* bright stars in the sextant telescope; and calculations depending on them are similar to those described for stars. The planetary declinations and the G. M. T.'s of their upper transits are given in the almanac, but not on the pages reprinted here.

The moon is now so rarely observed that we have not given examples of lunar observations.

Sometimes an "ex-meridian" observation of the sun or a star is made at a time very near the upper transit, on a day when the actual transit observation could not be secured because of clouds. There are special tables[1] for calculating observations of this kind; but we have not included them here because all such observations can be satisfactorily treated by a new general method to be explained later (p. 108).

Having now fully treated the older standard method of determining the ship's latitude, let us next consider the older way of obtaining the longitude. This cannot be done when the sun (or a star) is near its maximum altitude, as already explained (p. 88). The most favorable opportunity occurs when the observed object bears (p. 44) east or west; but it is not always possible to get the observation on such a bearing. In that case, the longitude observation, often called a "time-sight," must be taken when the sun is near the desired bearing, but always avoiding, if possible, observations at very low altitudes. And if a very low altitude has been observed in an emergency, it can sometimes be checked by a later observation at a better altitude.

The principle on which the time-sight depends is simple. Calculations based on the measured altitude make known the ship's mean time at the moment of observation. At the same moment the chronometer face (p. 93), duly corrected for error and rate, tells us the G. M. T. The difference between the two times then gives us the longitude (see p. 82).

The calculations for this problem are made by means of Table 4 (trigonometric logarithms) and Table 10 ("haversines"). These haversines (abbreviated hav.) are really additional trigonometric logarithms; and Table 10 gives in every case not only the haversine itself, which is really

[1] Tables 26 and 27 of Bowditch's "Navigator," for instance.

a logarithm, but also, in the adjoining heavy type columns, the number (abbreviated No.) of which the haversine is the log. This additional heavy type number is not given throughout the entire table, but only when necessary for working Sumner line calculations (see Chapter IX, p. 108). It is not needed in working time-sights.

The argument (p. 10) of the haversine table is a double argument, not to be confounded with the pairs of arguments already explained (p. 11). In the haversine table, the argument is generally given in degrees and minutes, as well as (for convenience) in hours and minutes of time, allowing the usual 15° to each hour, etc.

We shall now solve our time-sight problem for the sun; and in doing so shall make use of two angles not hitherto employed: the "polar distance" (abbreviated p), and the "half sum" (abbreviated s). We shall also, for brevity, indicate the ship's apparent solar time by T. Then we have the following formulas:

If lat. and dec. are both + or both − . . $p = 90° - \text{dec.}$ (1)
If lat. and dec. are one + and one − . . . $p = 90° + \text{dec.}$ (2)
In every case . . . . $s = \frac{1}{2}$ (alt. + lat. + p) (3)
If time-sight was made before noon, ship's time,

$$\text{hav. } (24^h - T) = \text{sec lat.} + \text{csc } p + \cos s + \sin (s - \text{alt.}) \quad (4)$$

If time-sight was made after noon, ship's time,

$$\text{hav. } T = \text{sec lat.} + \text{csc } p + \cos s + \sin (s - \text{alt.}) \quad (5)$$

In using these formulas, we have to choose between (1) and (2), and also between (4) and (5). Formula (3) is always used. No attention need be given to the signs of the declination or latitude except in choosing between formulas (1) and (2) for calculating p; and in choosing between (4) and (5), we have merely to note whether the time-sight was taken in the forenoon or afternoon by ship's time.

We also desire to emphasize especially that these formulas presuppose the latitude to be known. This is merely another application of the principle (p. 88) that both lati-

tude and longitude cannot be determined from a single observation. It follows that in using this method we must first determine the latitude by a noon-sight before we can calculate the time-sight for longitude. If the time-sight was taken in the afternoon, the noon-sight will naturally have preceded it, and the ship's latitude at noon will be known. This noon latitude must then be carried forward to the moment of the afternoon time-sight by D. R. methods (p. 7); and the latitude thus obtained must be used for calculating the time-sight.

But if the time-sight was a forenoon observation, it cannot be properly calculated until noon, when the latitude will be determined. After that, the latitude can be carried *backwards* by D. R. to the moment of the forenoon time-sight, and the latter can be calculated.

But if the navigator, because of emergency, needs his longitude at once, after taking the forenoon time-sight, he must obtain the latitude by a D. R. calculation based on the last good noon-sight. Most navigators calculate morning time-sights in this way, and then repeat the calculation after the new noon-sight has been obtained. The latter calculation will be preferable to the former, because the further the latitude is carried along by D. R., the less accurate will it be. And any error in the latitude used in the calculation will impress a consequent error on the calculated longitude.

We shall now work some time-sight examples. On board ship, at sea, Dec. 18, 1917, in the afternoon, D. R. latitude 42° 20′ N., D. R. longitude 35° 16′ W., the altitude of sun's lower limb was observed to be 14° 19′. The time was taken with the navigator's watch, and was $2^h\ 29^m\ 58^s$. A comparison of the watch and ship's chronometer gave C. $-$ W. $=$ $2^h\ 27^m\ 8^s$. The chronometer correction was $2^m\ 8^s$ slow of G. M. T. The index correction of the sextant was $+ 4'$; height of eye, 24 ft. Calculate the ship's longitude.

We have first to find, for the moment of the observation,

values of the declination and equation of time. To do this, we have:

Watch time of observation	2^h 29^m 58^s	(1)
C. – W.	2 27 8	(2)
Adding (1) and (2) gives chronometer time of observation	4 57 6	(3)
Chronometer correction, slow	2 8	(4)
Adding (3) and (4) gives G. M. T. of observation	4 59 14	(5)
For the G. M. T. (5) we interpolate the declination (p. 76), finding	– 23° 24′	(6)
and for the same G. M. T. we interpolate the equation of time	+ 3^m 21^s	(7)
Now, adding (5) and (7) gives Greenwich apparent time of observation	5^h 2^m 35^s	(8)

Next we inspect the formulas (p. 100), choosing (2) because latitude is + and declination –, and (5) because the sight was an afternoon one.

We now have, from line (6), declination (disregarding sign)	23°	24′	(9)
to which, by formula (2), we add	90	0	(10)
giving p	113	24	(11)
The observed altitude was	14	19	(12)
Index correction		+ 4	(13)
Adding (12) and (13) gives corrected altitude	14	23	(14)
Correction, Table 6		+ 12	(15)
Correction, Table 7		– 5	(16)
Adding (14), (15), (16) gives finally corrected altitude	14	30	(17)
The latitude by D. R. is	42	20	(18)
Adding (11), (17), (18) gives	170	14	(19)
Halving (19) gives (by formula (3), p. 100) s	85	7	(20)
Subtracting (17) from (20) gives (s – alt.)	70	37	(21)

Next we apply formula (5), p. 100. We have:

sec lat. (18) from Table 4, page 238	0.13121	(22)
csc p (11) from Table 4, page 219	0.03727	(23)
cos s (20) from Table 4, page 200	8.93007	(24)
sin (s – alt.) (21) from Table 4, page 215	9.97466	(25)
sum (22) to (25) = hav. T, by formula (5)	9.07321 [1]	(26)

[1] This sum has been diminished by 10 arbitrarily (see p. 25), which must always be done when the sum of logs is larger than 10.

T,[1] corresponding to (26) from Table 10, page 260, is	2^h	40^m	59^s	(27)
Greenwich apparent time (8) by watch and chronometer is	5	2	35	(28)
Subtract (27) from (28), giving time difference between ship and Greenwich................	2	21	36	(29)
Turning (29) into degrees with Table 9, page 249, gives..................................	35°	24′	W.	(30)

and (30) is the ship's longitude from this time-sight.

Upon comparing the D. R. longitude (35° 16′ W.) with the result of the time-sight (35° 24′ W.), we find that the ship is 8′ west of her D. R. position. This means, of course, that there has been a westerly "set" of current in the interval between the last accurate determination of longitude and the present one. It would be proper for the navigator to calculate from this the amount of westerly drift per hour, and to allow for it in carrying forward his longitude by D. R. from the present time-sight. It is also clear that the northerly or southerly set of the current can be similarly measured and allowed for by comparing the D. R. latitude with the latitude from a noon-sight (cf. p. 95). It is the general custom of navigators to ascribe such differences to ocean currents, never to uncertainty in the astronomic results. Dead reckoning is never allowed any weight as against a sextant observation.

The reader will have noticed that the foregoing calculation has been made in great detail, so that a beginner may have no difficulty in understanding it. But a practiced navigator would of course work the calculation in a much more condensed form, in such a way as to bring the logarithms next to the numbers to which they belong. We shall therefore now repeat the same example in such a condensed form:

[1] If the observation had been made before noon, we should have used formula (4) and should here have obtained $24^h - T$, instead of T. This $24^h - T$ would then be subtracted from 24^h, to get T, before continuing the calculation. Thus the form of calculation would contain another line between (27) and (28), in the case of a forenoon observation.

TIME-SIGHT, CONDENSED FORM. SUN

Watch time:	2^h	29^m	58^s	(1)	Obs'd alt.:	14°	19′	(12)
C. − W.:	2	27	8	(2)	Index:		+ 4	(13)
Chr. time:	4	57	6	(3)	Table 6:		+ 12	(15)
Chr. corr'n:	+	2	8	(4)	Table 7:		− 5	(16)
G. M. T.: 18^{th}	4	59	14	(5)	Corr'd alt.:	14	30	(17)
Eq. of time:	+	3	21	(7)				
G. app. time:	5	2	35	(8)				

Decl. 18^{th}, 4^h:	23° 23′.7		Eq. time, 18^{th}, 4^h:	$+ 3^m$	$22^s.3$	
H. D.:	0.1		H. D.:		1.2	
Decl. 4^h 59^m:	23 24	(6)	Eq. time, 4^h 59^m:	+ 3	21.1	(7)
p:	113 24	(11)				

Corr'd alt.:	14°	30′	(17)			
Lat., D. R.:	42	20	(18)	sec lat.:	0.13121	(22)
p:	113	24	(11)	csc p:	0.03727	(23)
sum of 3:	2)170	14	(19)			
s:	85	7	(20)	cos s:	8.93007	(24)
s − alt.:	70	37	(21)	sin (s − alt.):	9.97466	(25)
				sum of 4:	9.07321	(26) = hav. T (or $24^h - T$)[1]

T = ship's app. time:	2^h	40^m	59^s	(27)
By chron., Greenwich app. time:	5	2	35	(8)
Longitude:	2^h	21^m	36^s	(29)
or:	35°	24′	W.	(30)

When the object observed is a star or planet, the choice between formulas (4) and (5), p. 100, is not quite the same as in the case of a solar time-sight. We must use (4) if there is any east in the star's bearing at the moment of observation; and (5), if there is west in the bearing. The more nearly the star bears due east or west, the more accurate will be the resulting longitude. The use of formulas (1), (2), and (3) is the same as for the sun; but T, in the case of a star, is no longer the ship's apparent solar time. Instead, it is called

[1] See p. 103, footnote.

the star's "hour-angle." To get the longitude, we must first (p. 85) calculate the Greenwich sidereal time corresponding to the G. M. T. of the observation, as taken from the chronometer, duly corrected for error and rate; and then use the following formulas:

(6) Greenwich sid. time[1] − right-ascension of star = Greenwich hour-angle.

$$(7)\quad \begin{cases} \text{West long.} = \text{Greenwich hour-angle} - T, \\ \text{East long.} = T - \text{Greenwich hour-angle.} \end{cases}$$

As an example of a star observation we shall take the following:

At sea, just before sunrise, Dec. 17, 1917, off Cape Agulhas, latitude by D. R. 35° 20′ S., longitude by D. R. 20° 41′ E., the altitude of Sirius was measured, and found to be 40° 3′. The star bore west, and the height of eye was 22 ft. Index correction was + 5′. Time by watch, $16^h\ 29^m\ 48^s$, or $4^h\ 29^m\ 48^s$ A.M., civil time, Dec. 18; C. − W., − $1^h\ 23^m\ 50^s$; chronometer fast of G. M. T. $2^m\ 28^s$.

The calculation would proceed thus:

Watch time of observation	16^h	29^m	48^s	(1)
C. − W.	−1	23	50	(2)
Adding (1) and (2), having regard to − sign of (2), gives chronometer time of observation	15	5	58	(3)
Chronometer correction, fast..................		−2	28	(4)
Adding (3) and (4), having regard to − sign of (4), gives G. M. T. of observation..............	15	3	30	(5)
Right ascension mean sun, Greenwich mean noon, Dec. 17 (p. 83)..........................	17	42	10	(6)
Correction for "time past noon" (see p. 84)....		2	28	(7)
Adding (6) and (7) gives right ascension of mean sun..................................	17	44	38	(8)
Adding (5) and (8) (see p. 85) gives Greenwich sidereal time of the observation............	8[1]	48	8	(9)
Right ascension of Sirius, Dec. 17, is (p. 91)....	6	41	34	(10)
Subtracting (10) from (9) gives Greenwich hour-angle (formula (6), above)................	2	6	34	(11)

[1] 24^h may always be added or dropped here, if necessary.

Next we calculate T by formula (5), p. 100. We have:

Declination of Sirius, Dec. 17 (p. 92)	– 16° 36′	(12)
By formula (1), p. 100, subtract (12) from 90°, without attention to sign of (12), giving p..	73 24	(13)
The observed altitude was.	40 3	(14)
The index correction was......................	+ 5	(15)
Table 6 correction..........................	– 1	(16)
Table 7 correction..........................	– 5	(17)
Adding (14), (15), (16), (17), having regard to signs, gives corrected altitude	40 2	(18)
The latitude by D. R. was.	35 20	(19)
Adding (13), (18), and (19) gives	148 46	(20)
Halving (20) gives s........................	74 23	(21)
Subtracting (18) from (21) gives (s – altitude) ..	34 21	(22)

Now applying formula (5), page 100, we have :

sec latitude (19) from Table 4, page 231	0.08842	(23)
csc p (13) from Table 4, page 212	0.01849	(24)
cos s (21) from Table 4, page 211.................	9.43008	(25)
sin (s – altitude) (22) from Table 4, page 230	9.75147	(26)
Summing (23) to (26) gives hav. T, by form. (5) ..	9.28846 [1]	(27)
T [2] corresponding to (27), from Tab. 10, p. 263 is..	3^h 29^m 14^s	(28)
Difference between (28) and (11) is the longitude by formula (7), page 105...........	1 22 40 E.	(29)
Turning (29) into degrees with Table 9, page 249, gives...........................	20° 40′ E.	(30)

The D. R. longitude, 20° 41′ E., was therefore within 1′ of the longitude from this time-sight, and this shows that the ship has not been affected by ocean currents since the last observation. It is also interesting to note how near sunrise the observation was made. The twilight must have been quite strong, and the star therefore dim. But star observations can be made best in twilight because the horizon line can then be seen distinctly.

[1] This sum has also been diminished by 10 (see footnote, p. 102).

[2] Might be $24^h - T$, if the star bore E. instead of W. (see footnote, p. 103).

The foregoing example can of course also be arranged in condensed form, as follows:

TIME–SIGHT, CONDENSED FORM. STAR

Watch time:	16^h	29^m	48^s	(1)	Obs'd alt.:	40°	3′	(14)
C. – W.:	–1	23	50	(2)	Index:		+5	(15)
Chr. time:	15	5	58	(3)	Table 6:		– 1	(16)
Chr. corr'n:		– 2	28	(4)	Table 7:		– 5	(17)
G. M. T.:	15	3	30	(5)	Corr'd alt.:	40	2	(18)
R. A. mean sun:	17	42	10	(6)	Lat. D. R.:	35	20	(19)
Corr'n, past noon:		2	28	(7)	p:	73	24	(13)
Greenw'h sid. time:	8	48	8	(9)	sum:	2)148	46	(20)
R. A. of Sirius:	6	41	34	(10)	s:	74	23	(21)
Greenwich hour-ang.:	2	6	34	(11)	$(s - \text{alt.})$:	34	21	(22)
T., from (27):	3	29	14	(28)				
Long.:	1	22	40 E.	(29)				
or:		20°	40′ E.	(30)				

R. A. of Sirius:	6^h 41^m	34^s	(10)
Dec. of Sirius:	– 16°	36′	(12)
p:	73	24	(13)
sec lat.:	0.08842		(23)
csc. p:	0.01849		(24)
cos s:	9.43008		(25)
sin $(s - \text{alt.})$:	9.75147		(26)
sum of 4:	9.28846	(27)	= hav. T (or $24^h - T$)[1]

Having now fully explained both the noon-sight and the time-sight, we shall close this chapter with a strong recommendation to young navigators to familiarize themselves with the observation of stars. These always furnish a valuable check on sun observations: and at times of danger may save the ship when clouds have obscured the sun for days, and clearing occurs after sunset. It is easy to learn to know the principal stars from Jacoby's "Astronomy," Chapter III, "How to Know the Stars."

[1] See footnote, p. 103.

CHAPTER IX

NEWER NAVIGATION METHODS

THE reader may have noticed in Chapter VIII that there is a very definite difference between the determination of latitude by a noon-sight and longitude by a time-sight: for the latitude is obtained without previous knowledge of the longitude; but to get the longitude, a previous knowledge of the latitude is essential. This is, of course, a decided disadvantage in determining longitude, nor is there any practicable direct way to get the longitude without first knowing the latitude.

We have also seen (p. 101) that any existing uncertainty in our knowledge of the latitude will produce an error in the longitude computed from a time-sight. In situations of danger it is important to ascertain how great this longitude error may be. Suppose, for instance, we have calculated a time-sight with a D. R. latitude that we suspect may be as much as 10′ too small; and we wish to know how much our computed longitude may have been thereby put wrong. The obvious way to find out is to recompute the longitude with an assumed latitude 10′ larger than the D. R. latitude. The resulting longitude will then show the extreme range of error that must have been produced if the D. R. latitude was 10′ too small.

A third calculation, with an assumed latitude 10′ smaller than the D. R. latitude, will similarly exhibit the extreme possible range of longitude error in the other direction. Thus these two extra calculations will show the limits of longitude error that might be caused by a range of 20′ in the possible error of the D. R. latitude.

This rather obvious procedure was probably used long ago by more than one intelligent navigator; but it was first published in 1837 by Thomas H. Sumner, an American merchant captain. He used the method in dramatic circumstances of great danger; and he brought his ship safely into port. According to his own account, he made three calculations of the longitude, using three assumed latitudes differing by 10′, and he of course obtained three different longitudes. He then marked or plotted (p. 55) on his chart the point indicated by the first assumed latitude and its computed longitude. At this point the ship must have been located, if the first assumed latitude had been correct. The other two latitudes, with their computed longitudes, indicated two more points on the chart; and at one of these points the ship must have been, if either of these additional latitudes was correct.

Sumner found that the three points on the chart lay *in a straight line;* and it became at once evident that whatever latitude he might assume (within reason) he would always get a point on the same straight line, after computing the longitude. In other words, although he did not know his latitude accurately, and so could not compute his longitude accurately, yet he had found a straight line on the chart upon which his ship was surely situated.

Such a line can always be found in the way Sumner found it, or in some preferable modern way; and such a line we shall call a "Sumner line," though some writers on navigation prefer to call it a "line of position."

On the occasion of laying down his line, Sumner found that it passed directly through Small's Light, near the Irish coast; and as the line bore E.N.E. on his chart, he simply put the ship on that course, and in less than an hour he "made" Small's Light, actually bearing E.N.E. ½ E., and, as he says, "close aboard." He had had no observations after passing longitude 21° W., until the morning of Dec. 17, when these historic events occurred. He was off a rocky lee shore, in

the midst of a winter gale, after crossing the Atlantic; only a seaman can understand the relief he must have felt when that light suddenly appeared off the bow.

We have given this account of Sumner's experience to impress on the young navigator that he *must positively* familiarize himself with the Sumner method of navigation. Should we be so fortunate as to have any experienced navigator among our readers, we ask him to try the Sumner method once more, in the manner explained below, even if he may have found it troublesome in the past on account of certain difficulties in its application. For the Sumner method is the best method of navigation on all oceans and at all times: even when a noon-sight is available for latitude, it is better to treat it as a Sumner observation, and work out the Sumner line.

The principal objection urged against it by certain practical navigators arises from the small scale of existing ocean track charts, on which a distance of 10′ is represented by about $\frac{1}{8}$ inch. A line like Sumner's, 20′ long, would have only a length of $\frac{1}{4}$ inch on the chart; and such a little line would not be long enough to show accurately the direction in which it pointed. When near a coast, as in Sumner's case, this difficulty disappears, because navigators always have (or always *should* have and *use*) the large scale charts that can be obtained for coastwise waters.

But it is inconvenient for navigators to begin using a method off the coast, on the last day of a voyage, different from the form employed for many days at sea. Therefore, some authorities recommend the construction of a special large scale chart, with its latitude and longitude lines, each time an observation is made throughout the voyage, so that the Sumner line can always be drawn on a sufficiently large scale. It is no wonder that navigators have not generally adopted this somewhat laborious proceeding; and in the method given below we shall utilize the Sumner idea without requiring any lines to be drawn on charts.

Another objection to Sumner navigation is that it requires too much calculation; three longitude calculations for one observation, as Sumner practiced it. This objection is also quite removed now by the use of suitable tables such as we give in the present volume.

But before proceeding to explain these tables, we must outline briefly the real principle on which rests the complete utilization of the Sumner method on the open sea. There the navigator wants to know the ship's position in both latitude and longitude; and will not be satisfied with a mere line, with the ship "somewhere on the line." Along the coast such a line might help him to find Small's Light; but he is not looking for coast lights at sea.

And the Sumner method takes care of this matter in the simplest possible way. We have seen (p. 88) that two different observations are always necessary by any method to get both latitude and longitude. But two such observations by the Sumner method give two different lines on the chart: and as the ship must be located on both lines, her actual position must be at their point of intersection. We shall show how the required latitude and longitude of the ship at the point of intersection can be found by a simple calculation, without the drawing of any lines on the chart.

Coming now to the modern method of calculating a Sumner line, we must first state a general fundamental principle that may be easily verified by geometrical considerations. The true bearing (p. 44) of a Sumner line on a chart is always 90° greater than the true bearing or azimuth (p. 44) of the sun (or star) at the moment of observation. Or, in other words, the Sumner line bears at right angles to the sun at the time of observation.

We shall show how the bearing or azimuth of the sun can always be found from suitable "azimuth tables"; but the Sumner line is not completely known from its bearing alone. To locate it properly it is necessary to know in addition the latitude and longitude of *some point on the line*, which we

will call a "Sumner point." Then, knowing such a point of the line, and the bearing of the line, we may say we know the line completely, and, if necessary, could draw it on a chart.

Now to find the required Sumner point. We always have the D. R. position of the ship at the moment of observation; which we will call the "D. R. point." It is easy to find out if the D. R. point is also a Sumner point. It is merely necessary to calculate what the sun's altitude would be for a ship at the D. R. point, and then compare this calculated altitude with the one actually observed. If the D. R. point was really a Sumner point (which will rarely happen), the two altitudes will agree; if not, the amount of disagreement will show how far the D. R. point is distant from the nearest Sumner point.[1]

The first step, then, in Sumner navigation, is the calculation of the altitude, supposing the ship to be at the D. R. point at the moment of observation. To do this for a sun observation, we first calculate the Greenwich apparent time (abbreviated G. A. T.) of the observation, just as was done in the case of a time-sight on p. 102. To this G. A. T. we then add the ship's D. R. longitude, if east, or subtract it, if west, to get T (p. 100), the ship's apparent time of the observation. We then use the formulas on p. 113, in which X and Z are "auxiliary angles" required in the calculations, but not otherwise of special interest. These formulas are called the "cosine-haversine" formulas.

There are several other sets of formulas with which the same problem can be solved. One set, called the "haversine" formulas, involves the use of haversines only; another, called the "sine-cosine" formulas, solves the problem with sines and cosines. But neither is preferable to the following cosine-haversine set.

[1] This method is often called the Marcq Saint Hilaire method; but it should probably be credited to Lord Kelvin, who published "Tables for Facilitating Sumner's Method at Sea" in 1876. These tables follow the method described above.

If observation was made before noon, ship's time,

$$\text{hav. } X = \text{cos lat.} + \text{cos dec.} + \text{hav. } (24^h - T), \tag{1}$$

If observation was made after noon, ship's time,

$$\text{hav. } X = \text{cos lat.} + \text{cos dec.} + \text{hav. } T, \tag{2}$$

$$\text{lat.} - \text{dec.} = \text{diff.}^1 \text{ of lat. and dec., if both are } + \text{ or both } -, \tag{3}$$

$$\text{lat.} - \text{dec.} = \text{sum}^1 \text{ of lat. and dec. if one is } + \text{ and one } -, \tag{4}$$

$$\text{No. hav. } Z = \text{No. hav. (lat.} - \text{dec.)} + \text{No. hav. } X, \tag{5}$$

$$\text{Alt.} = 90° - Z. \tag{6}$$

Now we can compare the altitude computed by formula (6) with the observed altitude, fully corrected for index error, etc. The difference between the two altitudes in minutes will be the distance in miles of the nearest Sumner point from the D. R. point, for the minute and nautical mile here correspond, as they do in the case of differences of latitude (p. 15). The bearing of the Sumner point from the D. R. point will be the same as the sun's azimuth if the observed altitude is greater than the computed altitude: but if the observed altitude is less than the computed, the bearing of the Sumner point will be 180° greater than the sun's azimuth.

The bearing and distance of the Sumner point from the D. R. point once known, it is easy, by means of the traverse table (p. 10), to obtain the latitude and longitude of the Sumner point from the known latitude and longitude of the D. R. point; or, which is the same thing, from the ship's D. R. latitude and longitude.

Before giving examples of these calculations, it remains to show how the sun's bearing or azimuth can be taken from Table 11 (p. 284), called the azimuth table. The pair of arguments (p. 11) for entering this table are: first, in the left-hand column, the declination, which is here used without regard to its sign; and second, in the four topmost hori-

[1] In using formulas (3) and (4), pay no attention to + or − signs after the right formula is once chosen. The difference between latitude and declination is always taken by subtracting the smaller from the larger; and the sum by adding them, without regarding their + or − signs. Cf. also p. 89.

zontal lines, T (p. 100), the ship's apparent time at the moment of observation.

Having found this pair of arguments, we look in the column under T, and in the horizontal line opposite the declination. There we find an "index number." Next we look up the altitude, as computed by formula (6), page 113, in the right-hand column of the azimuth table, and follow along the horizontal line belonging to that altitude, until we reach a number equal (or nearly equal) to the index number. Then we go down the column containing this second appearance of the index number, and find the azimuth at the bottom of the page. The table gives approximate azimuths only, but the approximation is sufficient for our present purpose.

The azimuths at the bottom of the page appear in four horizontal lines, of which the upper two belong to forenoon observations, and the lower two to afternoon observations. All azimuths are counted from the north, through east, south, and west, from 0° to 360°, like compass courses in United States Navy practice (p. 41). It is important for the navigator to record, at the time of observation, the word "forenoon" or "afternoon," and also the sun's roughly approximate bearing, to aid in choosing which of the azimuths at the bottom of the tabular page is the right one. The record showing whether the observation was made in the forenoon or afternoon limits the choice to two of the lines of azimuths; and if there is any doubt remaining between these two, the following rules may clear it up.

When latitude is + and declination −, azimuth is between 90° and 270°;

When latitude is + and declination +, if declination is greater than latitude, azimuth is *not* between 90° and 270°;

When latitude is − and declination −, if declination is greater than latitude, azimuth is between 90° and 270°;

When latitude is − and declination +, azimuth is *not* between 90° and 270°.

In other cases, and especially when latitude and declination are nearly equal, the foregoing rules are insufficient, and we must consult Table 12 (p. 290), the "auxiliary azimuth table." This table has latitude and declination for its pair of arguments, the former in the left-hand vertical column, the latter in the topmost horizontal line: and in using the table it is not necessary to pay attention to the + and − signs of latitude and declination. Start with the latitude, and follow its horizontal line to the right until you reach the column having the declination at its head. There you will find an "auxiliary angle," which must be compared with the altitude computed by formula (6), page 113. Then:

If the computed altitude is greater than the auxiliary angle, and if latitude is +, azimuth is between 90° and 270°;

If the computed altitude is less than the auxiliary angle, and if latitude is −, azimuth is between 90° and 270°;

If the computed altitude is less than the auxiliary angle, and if latitude is +, azimuth is *not* between 90° and 270°;

If the computed altitude is greater than the auxiliary angle, and if latitude is −, azimuth is *not* between 90° and 270°.

It will rarely happen that any of the foregoing rules will be needed, if the navigator will make a careful observation of the sun's azimuth with the azimuth circle or pelorus (p. 44), as soon as possible after the sextant altitude has been observed. The ship's course should also be specially recorded when this observation is made. This proceeding is not merely a convenience to avoid consulting the foregoing rules in using the azimuth table: it is really essential to safe navigation, for a comparison of the observed azimuth with that derived from the table will make the compass error (p. 43) known. The variation is known from the chart; so that if we observe the compass error, we can allow for the variation, and get the deviation. This can then be compared with the deviation table (p. 48), to see if there has been any change in the compass since leaving port. It is

a great advantage of the Sumner method that the sun's azimuth comes out as a sort of by-product, so that the compass can be verified without any additional special calculations.

We shall now illustrate all the above considerations by means of examples; beginning with the observation already treated as a time-sight (p. 101). That observation we shall now work by the Sumner method. From page 101 we take the following:

Date of observation, Dec. 18, 1917, in the afternoon; D. R. latitude, 42° 20′ N.; D. R. longitude, 35° 16′ W.; altitude observed, 14° 19′; time by watch, $2^h\ 29^m\ 58^s$; C. − W., $2^h\ 27^m\ 8^s$; chronometer correction, $2^m\ 8^s$ slow of G. M. T.; index correction, + 4′; height of eye, 24 ft.

From the preparatory part of the calculation (p. 102), we also copy the following additional numbers:

Declination, line (6), page 102	−23° 24′	(1)
Greenwich apparent time (G. A. T.) of observation, line (8), page 102	$5^h\ 2^m\ 35^s$	(2)

We have next to calculate, by the formulas on page 113, the altitude corresponding to the D. R. point, for which the latitude and longitude are given above. The longitude is 35° 16′ W., or, at 15° to the hour (Table 9, p. 249):

D. R. longitude is	$2^h\ 21^m\ 4^s$ W.	(3)
Subtracting (3) from (2), according to page 112, gives ship's apparent time of observation, T ..	2 41 31	(4)

We are now prepared to apply formulas (1) to (6), page 113. We choose formula (2) for an afternoon observation [1]; and write:

[1] For a forenoon observation we should choose formula (1), and should therefore need to know $24^h - T$ instead of T. This would make necessary another line in the form of calculation, and it would follow line (4). This new line might be numbered (4′); and in it would be written $24^h - T$, obtained by subtracting T (line 4) from 24^h.

Cos lat., 42° 20′ N. by D. R. (see Table 4, p. 238)....	9.86879	(5)
Cos dec., 23° 24′, line (1) (see Table 4, p. 219)......	9.96273	(6)
Hav. T, $2^h\ 41^m\ 31^s$, line (4) (see Table 10, p. 260)....	9.07596	(7)
Adding (5) to (7) gives hav. X (dropping 20, p. 25)..	8.90748	(8)

Now we choose formula (4), because latitude and declination are + and −;

The latitude is, by D. R..........................	42° 20′	(9)
Adding (1) and (9) according to formula (4) gives (lat. − dec.)................................	65° 44′	(10)
Now we have, Table 10, page 266, No. hav. of (10)..	0.29451	(11)
No. hav. X,[1] line (8)..........................	0.08082	(12)
Adding (11) and (12), according to formula (5), page 113, gives No. hav. Z......................	0.37533	(13)
And Z, corresponding to (13) is found from Table 10, page 268	75° 34′	(14)
Then, by formula (6) computed altitude = 90° − Z (14), or	14° 26′	(15)

This computed altitude (15) must now be compared with the observed altitude, fully corrected. We find:

Obs'd alt., fully corrected, line (17), page 102, is.....	14° 30′	(16)
Difference between (15) and (16), in minutes, is the distance of Sumner point from D. R. point in miles (p. 113). It is.........................	4 miles	(17)

Next we must find the sun's azimuth from Table 11, page 286. The top argument for entering the table is T, line (4), and it must be found in the "afternoon" lines. The argument for the left-hand column is the declination, line (1). Under T, and opposite declination, we find the tabular index number 5872.[2] Then we find the computed altitude, line (15), in the right-hand column of Table 11, page 286, and

[1] This No. hav. X comes from Table 10, page 258, without looking up the angle X at all. We simply find hav. X in the table, and take the No. hav. X out of the adjoining heavy type column. No interpolations are needed, the nearest tabular numbers being sufficiently accurate.

[2] The index numbers and the azimuth need not be very accurate: it is sufficient to use the nearest tabular arguments, so that interpolation is not essential.

follow its horizontal line till we again come upon the index number 5872. It lies about halfway between 5703 and 5973. Going down the two columns containing these index numbers, we find in the afternoon azimuth lines two values of the azimuth, 217° and 323°. The choice between these two numbers would be very easy, if the observer's record contained even a rough estimate of the sun's bearing at the time of observation. We have purposely not made this available, so as to show how to consult the directions on page 114, and there we find that when the latitude is + and the declination −, the azimuth is between 90° and 270°. So we finally choose 217° for the sun's azimuth.

Since the observed altitude (16) is greater than the computed altitude (15), the bearing of the Sumner point from the D. R. point, according to page 113, is the same as the sun's azimuth, or 217°. And as we now know the bearing and distance of the Sumner point from the D. R. point, we can find its latitude and longitude by a simple application of the traverse table (p. 154).

We have merely to consider the bearing and distance to be a course angle and distance, and imagine a ship to have sailed from the one point to the other. In the present case, the distance is 4 miles (line 17), the course 217° : and Table 1 (p. 164) gives the corresponding latitude 3′.2, departure 2.4. The longitude difference is obtained from the departure by Table 2 (p. 174) and is, for latitude 42°, about 3′.2. Dropping odd fractions, the latitude difference and longitude difference both come out 3′. The Sumner point is therefore 3′ distant from the D. R. point in both latitude and longitude. And since the bearing 217° indicates on the compass card that the Sumner point is south and west of the D. R. point, it follows that:

Lat. of Sumner point = D. R. lat. − 3′ =		
42° 20′ N. (line 9) − 3′	42° 17′ N.	(18)
Long. of Sumner point = D. R. long. + 3′	35 19 W.	(19)
Azimuth of Sumner line (p. 111)	307°	(20)

It is important for the reader to understand that the foregoing calculation is given in extended detail so as to make it easy for the beginner to follow. In condensed form, we should have the following arrangement of the calculation, corresponding to the condensed time-sight form (p. 104). Part of the work here repeated from page 104 has no attached reference numbers in parentheses: the new part of the work has references to the detailed calculation just given.

SUMNER LINE, CONDENSED FORM. SUN

Obs'd alt.:	14° 19′	Decl. 4^h:	23° 23′.7 S.
Index:	+ 4	H. D.:	0.1
Table 6:	+ 12	Decl. $4^h\,59^m$:	23° 24′ S.
Table 7:	− 5	Eq. time, 4^h:	+ $3^m\,22^s.3$
Corr'd alt.:	14° 30′	H. D.:	1.2
		Eq. time, $4^h\,59^m$:	+ 3 21.1

Watch time:	$2^h\,29^m\,58^s$				
C. − W..	2 27 8				
Chr. time:	4 57 6				
Chr. corr'n:	+ 2 8				
G. M. T. 18th:	4 59 14				
Eq. of time:	+ 3 21				
G. app. time:	5 2 35				
D. R. long.:	2 21 4 W.	(3)			
Ship's app. time, T:	2 41 31	(4)	hav. T (or $24^h - T$)[1]:	9.07596	
D. R. lat.:	42° 20′ N.	(9)	cos lat.:	9.86879	
Dec.:	23 24 S.	(1)	cos dec.:	9.96273	
			sum = hav. X:	8.90748	
			No. hav. X:	0.08082	(12)
Lat. − Dec.:	65 44	(10)	No. hav. (lat. − dec.):	0.29451	(11)
Z:	75 34	(14)	No. hav. Z	0.37533	(13)
Comp'd alt.:	14 26	(15)			
Obs'd alt.:	14 30	(16)			
Diff.:	4	(17)			
Index No.:	5872				
Azimuth:	217°				
Lat. diff.:	3′.2		Dep.:	2.4	
			Long. diff.:	3′.2	
D. R. lat.:	42° 20′ N.	(9)	D. R. long.:	35° 16′ W.	(3)
Sumner pt. lat.:	42 17 N.	(18)	Sumner pt. long.:	35 19 W.	(19)
Azimuth of Sumner line:	307°	(20)			

[1] See footnote, p. 116.

When the object observed is a star (cf. p. 104) or planet, the choice between formulas (1) and (2), page 113, is not quite the same as in the case of a solar observation. We must use formula (1) if the star was on the east side of the sky when observed, which might be called a "forenoon" observation of the star; and we must use (2) if the star was on the west side of the sky, giving an "afternoon" star observation. The use of the remaining formulas (3) to (6) is the same as for the sun; but T is now no longer the ship's apparent time. Instead, it is the star's hour-angle (p. 104); to find it for use in formulas (1) and (2), and in Table 11, we must first calculate (p. 85) the Greenwich sidereal time corresponding to the G. M. T. of the observation, as taken from the chronometer, duly corrected for error and rate; and then use the following formulas:

(7) Greenwich hour-angle = Greenwich sidereal time − right ascension of star,

$$(8) \begin{cases} T = \text{Greenwich hour-angle} + \text{D. R. longitude, if east,} \\ T = \text{Greenwich hour-angle} - \text{D. R. longitude, if west.} \end{cases}$$

As an application of the Sumner method to a star observation, let us take the observation of Sirius, Dec. 17, 1917, off Cape Agulhas, already treated as a time-sight (p. 105).

From the preliminary calculations there given, we have:

Greenwich hour-angle, line (11), page 105	2^h	6^m	34^s	(1)
D. R. longitude (p. 105) is 20° 41′ E., or by Table 9 (p. 249)	1	22	44 E.	(2)
By formula (8) above, we add (1) and (2), giving T	3	29	18	(3)

The star bore west[1] (p. 105) so we choose formula (2) (p. 113), and write:

cos lat. (p. 106, line 19), 35° 20′ S. by D. R. (see Table 4, p. 231)	9.91158	(4)
cos dec. (p. 106, line 12), − 16° 36′ (Tab. 4, p. 212)	9.98151	(5)
hav. T, $3^h\ 29^m\ 18^s$ (line 3, above) (see Table 10, p. 263)	9.28872	(6)
Adding (4) to (6) gives, by formula (2), page 113, hav. X,	9.18181[2]	(7)

[1] See p. 116, footnote.

[2] Sum diminished by 20 (see footnote, p. 102).

Next we choose formula (3), page 113, since latitude and declination are both −. We have:		
By formula (3), lat. − dec. = 35° 20′ − 16° 36′ =	18° 44′	(8)
We now use formula (5), page 113. We have:		
No. hav. 18° 44′ (8) (see Table 10, p. 254)	0.02649	(9)
No. hav. X[1] (7) (see Table 10, p. 261)	0.15194	(10)
Adding (9) and (10) gives No. hav. Z	0.17843	(11)
And Z, corresponding to (11) is found from Table 10, page 262	49° 59′	(12)
Then, by formula (6), page 113, computed alt. = 90° − Z (12), or	40° 1′	(13)
This computed altitude (13) must be compared with the observed altitude, fully corrected.		
This was (p. 106, line 18)	40° 2′	(14)
Difference between (13) and (14), in minutes, or distance of Sumner point from D. R. point in miles (p. 113)	1 mile	(15)

Next we find the star's azimuth from Table 11, page 287. The top argument for entering the table is T, line (3), and it must be found in the "afternoon" lines, since the star bore W. The argument for the left-hand column is the declination, line (5). Under T (p. 287), and opposite declination, we find (approximately) the tabular index number 7550. Then we find the computed altitude, 40° (13), in the right-hand column of the table (p. 289), and follow along its horizontal line until we again reach the index number 7550. The nearest to 7550 is 7544; and under this number, at the foot of the column, we find the two "afternoon" azimuths 260° and 280°.

These two numbers are so nearly equal that there is uncertainty in choosing between them. Had the observer taken the star's bearing by compass at the time of observation (p. 115), the uncertainty would be removed. But in the absence of this information, we must have recourse to Table 12 (p. 290), the auxiliary azimuth table. Entering this table with the pair of arguments of the present

[1] No. hav. here obtained from hav. without finding the angle X (p. 117, footnote).

problem: viz. latitude 35°, declination 17°, we find the auxiliary angle 31°. The computed altitude (13) being 40°, is greater than the auxiliary angle, and the latitude is −. Therefore, by the instructions (p. 115), the azimuth is *not* between 90° and 270°. We therefore choose 280° as our final azimuth, since 260°, the other possible value, is in the prohibited area between 90° and 270°.

The computed altitude (13) being less than the observed altitude, this observation places the Sumner point 1 mile (15) from the D. R. point, and bearing from it 280°, the same as the star's azimuth (p. 113). The traverse table (p. 156) gives, for distance 1 and course 280°, latitude 0.2, departure 1.0. The longitude difference, by Table 2 (p. 172), is 1′.2, for the departure 1.0. Therefore, since azimuth 280° indicates on the compass card that the Sumner point is W. and N. of the D. R. point, we have:

lat. of Sumner point = − 35° 20′ (4) + 0′.2 = − 35° 20′ (16)
long. of Sumner point = 20° 41′ E. (2) − 1′.2 = 20° 40′ E. (17)

The bearing of the Sumner line will be 90° greater than the star's azimuth (p. 111); so we have:

Bearing of Sumner line = 280° + 90° = 370°; or,
dropping 360° = 10° (18)

The foregoing calculation of the Sumner point from a star observation can of course also be put in condensed form. In doing so, we have repeated certain numbers from page 107 without references in parentheses. But numbers taken from the extended calculation just given have their reference numbers attached.

This condensed form, like the others previously given, is the form of calculation which would be used in actual navigation. It is most important, in the interest of numerical accuracy, to make all calculations upon forms; and no numbers should be written on the forms without having an adjoining statement as to the meaning of the numbers.

SUMNER LINE, CONDENSED FORM. STAR

Watch time:	16^h	29^m	48^s			
C. – W.:	– 1	23	50			
Chr. time:	15	5	58			
Chr. corr'n:		– 2	28		Obs'd alt.:	40° 3′
G. M. T.:	15	3	30		Index:	+ 5
R. A. mean sun:	17	42	10		Table 6:	– 1
Corr'n, past noon:		2	28		Table 7:	– 5
Greenw'h sid. time:	8	48	8		Corr'd alt.:	40 2
R. A. of Sirius:	6	41	34			
Greenw'h hour-angle:	2	6	34			
D. R. long.:	1	22	44 E.	(2)		
T:	3	29	18	(3)		

T or $(24^h - T)$[1]:	3^h 29^m 18^s	(3) hav.:	9.28872	(6)
Dec.:	– 16° 36′	cos:	9.98151	(5)
D. R. lat.:	– 35 20	cos:	9.91158	(4)
Sum of 3 = hav. X:			9.18181	(7)
No. hav. X:			0.15194	(10)
Lat. – Dec.:	18° 44′	(8); No. hav.:	0.02649	(9)
Sum of 2 = No. hav. Z:			0.17843	(11)
Z:			49° 59′	(12)
Computed alt. = 90° – Z:			40 1	(13)
Obs'd alt., corr'd:			40 2	(14)
Diff.:			1	(15)

Index No.: 7550
Azimuth: 280°
Lat. diff.: 0′.2 Dep.: 1.0 Long. diff.: 1′.2
Sumner pt. lat.: – 35° 20′ (16); long.: 20° 40′ E. (17)
Bearing of Sumner line: 10° (18)

We have now, in the foregoing examples, illustrated the manner of determining a Sumner line completely by ascertaining the latitude and longitude of one point on the line (the Sumner point), and the bearing of the line itself at that point. It may be desired to draw the line on the chart, which will always interest the navigator if he is near the coast and has a large-scale chart. To draw it, we merely locate the Sumner point on the chart by its latitude and longi-

[1] See footnote, p. 116.

tude, and then draw the line through the point so that it will make with the meridian an angle equal to the bearing which has been computed for the line. The Sumner line should be extended in *both* directions from the Sumner point, for any convenient distance, in such a way that the point will be near the middle of the line.

We can now gain a better understanding as to Sumner navigation by comparing the results obtained in one of the foregoing examples with the corresponding calculation of the same example as a time-sight. Thus from the same observation (pp. 104, 119)

As a Time-Sight	As a Sumner Observation
From D. R. latitude 42° 20′ N.; D. R. longitude 35° 16′ W., we found the ship's longitude to be 35° 24′ W.	From D. R. latitude 42° 20′ N.; D. R. longitude 35° 16′ W., we found the Sumner point to be in latitude 42° 17′; longitude 35° 19′ W.; and azimuth of Sumner line, 307°.

Starting with the same observed altitude, and the same D. R. position of the ship, we get quite different results by the two methods of calculation. The time-sight gives us nothing but a longitude; and it will be the correct ship's longitude only if the D. R. latitude was also correct (p. 101). Therefore the time-sight calculation leaves us with *both* latitude and longitude still affected by possible errors in the D. R. latitude.

On the other hand, the Sumner calculation gives us both a latitude and a longitude, but neither belongs to the ship's position. They both belong to the position of the Sumner point, but they are free from the effects of any D. R. errors. They fix the Sumner point only, but they fix it *correctly*. Furthermore, our knowledge that the ship is somewhere on the Sumner line is also a fact, free from error. So what we learn from the Sumner method is sure; what we get by the older methods is all really D. R. information in some

degree. The Sumner method is independent of D. R., an advantage of which the value cannot be estimated too highly.

Furthermore, it can be shown mathematically (cf. p. 111) that a single observation can never really do more than determine a line on which the ship must be. Even a noon-sight does no more than this; for in determining the ship's latitude, it really only makes known a horizontal line (the ship's latitude parallel) on the chart. In other words, for a noon-sight the Sumner line is horizontal, or has a bearing of 90°. And it will always come out 90°, if a noon-sight is worked as a Sumner observation.

But the principal purpose of our present comparison of the two methods of calculation is to warn the navigator against falling into the error of imagining the ship to be at the Sumner point. The observation does no more than tell us where the Sumner point is, and that the ship is somewhere on the line; so far as the observation is concerned, all points on the line are equally likely to be the ship's true position. Therefore it is misleading to call the Sumner point the ship's "most probable position." Were it so, a second observation, made later in the day, would give another "most probable position" of the ship. We should then be naturally led to take as the ship's final location a point midway between the two "most probables," ascribing their divergence to possible errors of observation. But the ship's real position we already know (p. 111) to be at the *intersection* of the two Sumner lines resulting from the two observations. And this intersecting point may be many miles from both "most probables," and from the above-mentioned midpoint between them.

Less than two observations cannot fix the ship's position completely; when two have been made, a correct application of the Sumner method requires that the intersection point of two Sumner lines be determined by calculation. But before explaining the method of doing this, we must describe an excellent alternative way of making Sumner

calculations such as we have given in the above examples. The results are the same results as before, but they are obtained with less work, and quite without logarithms, by means of special tables such as our Table 13 (p. 292),[1] which we shall call Kelvin's Sumner Line Table.

This table has a pair of arguments (p. 11), a and b, a appearing at the heads of the tabular columns, and b in the left-hand column of each page. Corresponding to these two arguments, the table gives two angles, K and Q; so that whenever a and b are given we can find the corresponding K and Q; or, if a and K should be given, we can find the corresponding b and Q.

In the Sumner problem we obtain, by preparatory calculation (cf. pp. 119, 123), the following data:

Declination of sun (or star); D. R. latitude; D. R. longitude; T, the ship's apparent time of the observation for the sun, or the hour-angle for a star;

and we wish to get the computed altitude and the azimuth.

The principle on which Table 13 depends is that the D. R. latitude and longitude being always somewhat uncertain, we can, if we choose, change them by reasonable amounts before beginning our calculations. The Sumner point will then be determined by its distance and bearing from the *changed* D. R. point, instead of the original D. R. point. By this device the tabular calculation is much facilitated. The use of the table is easy after a little practice, the work being divided into a series of separate operations. In describing these operations we have used small subscript numbers, to distinguish the several arguments, etc.; as, for instance, in Operation 1 we use a_1, b_1, K_1.

[1] These tables were first published by Lord Kelvin in 1876. More extended ones were recently issued by Lieutenant de Aquino, of the Brazilian Navy; and these were reprinted by the Hydrographic Office, United States Navy, in 1917. Aquino also improved Kelvin's method of using his table.

OPERATION 1, requiring no interpolation. Enter Table 13 with:

Arg. $a_1 =$ declination, taken without regard to $+$ or $-$ sign, and correct to the nearest whole degree only;
Arg. $b_1 = T$, if T is between 0^h and 6^h;
$= 12^h - T$, if T is between 6^h and 12^h;
$= T - 12^h$, if T is between 12^h and 18^h;
$= 24^h - T$, if T is between 18^h and 24^h;
and before use b_1 must be turned into degrees with Table 9 (p. 249). It need be correct to the nearest degree only. This proceeding will make b_1 always less than 90°.

Then take from the table the tabular angle K_1, also correct to the nearest degree only.

OPERATION 2, requiring simple interpolation. Enter the table a second time with:

Arg. a_2 = the K_1, obtained in Operation 1.

Then, under this a_2, run down the K-column until you find the declination (taken without regard to $+$ or $-$ sign); so that, in other words, K_2 = declination.

Take from the table the angle Q_2, which stands next to the declination K_2, and also the b_2, which is in the left-hand argument column, in the same horizontal line with the declination K_2 in the K-column. It will rarely be possible to find the declination (which must this time be exact to the nearest minute) in the K-column; so that a simple interpolation will be necessary in getting Q_2 and b_2. An example of this interpolation will be found on page 129; and, as we shall see, it is practically the only numerical calculation required in the whole problem. The Kelvin method is very much shorter than it looks.

The angle Q_2 is used in choosing the longitude of the "changed D. R. point"; the latitude of that point will be found in Operation 3. To utilize Q_2 for a sun observation, calculate the Greenwich apparent time (G. A. T.) of the

observation, as on page 102, line (8), and turn it into degrees with Table 9 (page 249). Then:

(1) W. long. of changed D. R. point = G. A. T. $- Q_2$, if, in Operation 1, T was less than 6^h;
(2) W. long. of changed D. R. point = G. A. T. $- (180° - Q_2)$ if, in Operation 1, T was between 6^h and 12^h;
(3) W. long. of changed D. R. point = G. A. T. $- (180° + Q_2)$ if, in Operation 1, T was between 12^h and 18^h;
(4) W. long. of changed D. R. point = G. A. T. $- (360° - Q_2)$ if, in Operation 1, T was between 18^h and 24^h.

When the subtractions in these formulas cannot be made, the G. A. T. may be increased by 360°; and when the west longitude comes out greater than 180°, subtract it from 360°, and call it east longitude.

In the case of a star, we must use, in the above formulas, the Greenwich hour-angle, instead of the G. A. T. See page 105, line (11), for the method of obtaining it.

Operation 3, requiring no interpolation. Enter the table a third time with:

Arg. $a_3 = K_1$, again as obtained in Operation 1.
(5) Arg. $b_3 = 90° - (b_2 +$ changed D. R. lat.), if latitude and declination are of opposite signs, one + and one −;
(6) Arg. $b_3 = (b_2 +$ changed D. R. lat.) $- 90°$, if T was between 90° and 270°;
(7) Arg. $b_3 = 90° - (b_2 -$ changed D. R. lat.), if latitude is less than b_2;
(8) Arg. $b_3 = 90° + (b_2 -$ changed D. R. lat.), if latitude is greater than b_2.

In choosing among formulas (5) to (8), give them precedence in order; do not use (7) or (8) if the conditions stated for (5) or (6) are satisfied. And at this point, use your privilege of choosing any reasonable changed D. R. latitude for the ship; and choose one that differs as little as possible from the original D. R. latitude, and that yet makes b_3 a whole number of degrees. In this way, all further

interpolation is avoided. Having once chosen among the formulas, the latitude is used without regard to + or − signs.

To complete Operation 3, having entered the table with the pair of arguments a_3 and b_3, take out the tabular K_3 and Q_3.

K_3 is now the computed altitude, to be used (p. 113) in locating the Sumner point from the changed D. R. point; and Q_3 is the sun's true azimuth, which will always come from the table less than 90°. If the ship is in the northern hemisphere, this azimuth must be counted from the north point of the horizon if, in Operation 3, we used formulas (6) or (7); or from the south point of the horizon, if we used formulas (5) or (8). With the ship in the southern hemisphere, interchange the north and south points of the horizon in these directions. And in both hemispheres, the azimuth will of course be counted toward the east or west, according as the observation was a "forenoon" or "afternoon" one (cf. p. 120).

We shall now use Table 13 for the example given on page 119 in condensed form. We have (p. 127):

Operation 1.

a_1 = dec. = 23°, p. 119, line (1), to the nearest degree;

$b_1 = T = 2^h\ 41^m\ 31^s$, p. 119, line (4) = 40°, to the nearest degree; and, with a_1 and b_1 as arguments, Table 13 gives (p. 298): K_1 = 36°, to the nearest degree.

Operation 2.

$$a_2 = K_1 = 36°.$$
$$K_2 = 23°\ 24', \text{ p. 119, line (1)}$$

and, with a_2 and K_2, we must find Q_2 and b_2. Running down the column headed a = 36° (p. 302), we find:

When K_2 = 23° 5′, Q_2 = 39° 43′, b_2 = 29°,
When K_2 = 23° 51′, Q_2 = 40° 0′, b_2 = 30°.

We wish to interpolate for K_2 = 23° 24′, which is 19′ down from 23° 5′ toward 23° 51′. The whole distance from

23° 5′ to 23° 51′ is 46′. Therefore we must interpolate down $\frac{19}{46}$ of the whole interval from $Q_2 = 39° 43'$ to $Q_2 = 40° 0'$. The difference between these two Q_2's is 17′; therefore the final Q_2, belonging to $K_2 = 23° 24'$, is $39° 43' + \frac{19}{46} \times 17' = 39° 43' + 7' = 39° 50'$. Similarly, the difference between the two b_2's being 60′, the final value of b_2, for $K_2 = 23° 24'$, is $29° + \frac{19}{46} \times 60' = 29° 25'$. These two little interpolations are *practically all the calculation* required in the whole problem.

To find the longitude of the changed D. R. point from the above $Q_2 = 39° 50'$, we take from page 102, line (8),

Greenwich apparent time of observation,	$5^h 2^m 35^s$
which, by Table 9 (p. 249) is,	75° 39′

We now use formula (1), page 128, because T, in Operation 1, was less than 6^h. We get:

W. long. of ch'd D. R. pt. = G. A. T. − Q_2 = 75° 39′ − 39° 50′
= 35° 49′ W.

Operation 3.

$$a_3 = K_1 = 36°.$$

The D. R. latitude is + 42° 20′ (p. 119, line (9)); and as the declination is −, we choose formula (5), page 128. This, *without* changing the D. R. latitude, would give $b_3 = 90° - (b_2 + \text{D. R. lat.}) = 90° - (29° 25' + 42° 20') = 90° - 71° 45'$; but by choosing a *changed* D. R. latitude of 42° 35′, we shall make b_3 a whole number of degrees. So we have: $b_3 = 90° - (b_2 + \text{changed D. R. latitude}) = 90° - (29° 25' + 42° 35') = 90° - 72° = 18°$.

Now we enter the table with the arguments $a_3 = 36°$, and $b_3 = 18°$, and obtain, without interpolation (p. 302):

K_3 = computed altitude = 14° 29′,
Q_3 = sun's true azimuth = 37° 22′.

This azimuth must be counted from the south point of the horizon, since we used formula (5) in Operation 3; and

as the observation was an afternoon one, the correct azimuth will be S. 37° 22′ W. (cf. p. 19). Counted in the United States Navy way, from the north toward the east, and so around to 360°, the azimuth will be 217° 22′.

On page 119, we found: Computed altitude, 14° 26′; azimuth, 217°.

This computed altitude differs by 3′ from the value just found by Table 13. The difference is due to our having changed the D. R. point.

From the changed D. R. point, in latitude 42° 35′ N.; longitude 35° 49′ W., we now calculate (see Condensed Form, next page) the position of the Sumner point to be: latitude 42° 34′ N.; longitude 35° 50′ W. The former position, as obtained on page 119, was: latitude 42° 17′ N.; longitude 35° 19′ W.

These two Sumner point positions should lie on the same Sumner line if the method of Table 13 gives correct results; and they will satisfy this test, if the bearing of a line joining them agrees with the azimuth of the Sumner line, which is 217° + 90° = 307°. From the two Sumner point positions we have: latitude difference = 17′; longitude difference = 31′; departure (Table 2, p. 174) = 23.0. The traverse table (p. 164) gives, for latitude 17, departure 23.0, the distance 28, course 307°. The agreement is perfect, and shows that the same Sumner line passes through both points, though they are 28 miles apart. This test also shows that the calculation may indicate *any* point on the Sumner line as *the* Sumner point, if the D. R. position of the ship is uncertain: and so we again call attention to the error of taking the calculated Sumner point as the ship's most probable position (cf. p. 125).

We now, as usual, repeat the above calculation by Table 13, in condensed form, and including the final determination of the position of the Sumner point from the changed D. R. point.

SUMNER LINE BY TABLE 13, CONDENSED FORM. SUN

[The following is taken from page 119.]

Decl., 4^h:	$-23°\ 23'.7$	Eq. of time:	$+3^m\ 22^s.3$
H. D. :	0.1	H. D.:	1.2
Decl., $4^h\ 59^m$:	$-23\ \ 24$	Eq. time:	$+3\ \ 21.1$

Watch time:	2^h	29^m	58^s		Obs'd alt.:	14° 19′
C. − W.:	2	27	8		Index:	+ 4
Chr. time:	4	57	6		Table 6:	+ 12
Chr. corr'n:		+ 2	8		Table 7:	− 5
G. M. T.:	4	59	14		Corr'd alt.:	14 30
Eq. of time:		+ 3	21		D. R. lat.:	42° 20′ N.
G. app. time:	5	2	35		D. R. long.:	35° 16′ W.
D. R. long.:	2	21	4 W.	(3)		
Ship's app. time, T:	2	41	31	(4)		

[The following is calculated with Table 13.]

Operation 1

a_1 = dec. = 23°
$b_1 = T$ = $2^h\ 41^m\ 31^s$(4)
= 40°
Table 13, K_1 = 36°

Operation 2

$a_2 = K_1$ = 36°
K_2 = dec. = 23° 24′
Table 13, Q_2 = 39° 50′
Table 13, b_2 = 29° 25′
Greenwich app. time = $5^h\ 2^m\ 35^s$ = 75° 39′
By page 128, form. (1), W. long. of changed D. R. pt. = G. A. T. − Q_2
= 35° 49′ W.
Lat. of changed D. R. pt. = 42° 35′ N.

Operation 3

$a_3 = K_1$ = 36°
b_3 = 90° − (b_2 + changed D. R. lat.) = 18°
Table 13, K_3 = comp'd alt. = 14° 29′
Table 13, Q_3 = azimuth of sun = 37° 22′
or, by U. S. Navy = 217° 22′
Azimuth of Sumner line = 217° 22′ + 90°
= 307° 22′

Dist. of Sumner pt. from changed
D. R. pt. = corr'd obs'd alt. − comp'd alt. = 1′ or 1 mile
Bearing of Sumner pt. from changed D. R. pt. = 217°,
since comp'd alt. is less than obs'd alt.
Dist. 1, on course 217°, gives lat. diff., 0′.8; dep., 0.6; long. diff., 0′.8
Lat. of Sumner pt. = lat. of ch'd D. R. pt. − lat. diff. = 42° 34′ N.
Long. of Sumner pt. = long. of ch'd D. R. pt. + long. diff. = 35° 50′ W.

A practised navigator can make the above complete calculation in a few minutes, as there are no logs used; and any one can easily obtain the necessary practice at sea by simply forming the habit of working his sights both as time-sights and as Sumners. To illustrate the subject further, we now give, in condensed form, the Star Example of p. 123, worked by Table 13.

SUMNER LINE BY TABLE 13, CONDENSED FORM. STAR

[The following is taken from page 123.]

Watch time:	16^h	29^m	48^s
C. – W.:	– 1	23	50
Chr. time:	15	5	58
Chr. corr'n:		– 2	28
G. M. T.:	15	3	30
R. A. mean sun:	17	42	10
Corr'n, past noon:		2	28
Greenwich sid. time:	8	48	8
R. A. of Sirius:	6	41	34
Green. hour-angle:	2	6	34
D. R. long.:	1	22	44 E.
T:	3	29	18

Obs'd alt.:	40°	3′
Index:		+ 5
Table 6:		– 1
Table 7:		– 5
Corr'd obs'd alt.:	40	2
Dec. of Sirius:	– 16	36
D. R. lat.:	– 35	20

[The following is calculated with Table 13.]

OPERATION 1

a_1 = dec. = 17°
$b_1 = T$ = 3^h 29^m 18^s
= 52°
Table 13, K_1 = 49°

OPERATION 2

a_2 = K_1 = 49°
K_2 = dec. = 16° 36′
Table 13, Q_2 = 51° 57′
Table 13, b_2 = 25° 49′

By page 128, form. (1),
W. long. of changed D. R. pt. = Green. hour-angle – Q_2[1]
= 339° 41′
= 20° 19′ E.
Lat. of changed D. R. pt. = – 35° 49′

OPERATION 3

a_3 = K_1 = 49°
By form. (8), page 128, b_3 = 90° + (b_2 – changed D. R. lat.) = 80°
Table 13, K_3 = comp'd alt. = 40° 15′
Table 13, Q_3 = az. of Sirius = N. 81° 25′ W.
or, by U. S. Navy = 278° 35′
Az. of Sumner line = 368° 35′, or 8° 35′

Dist. of Sumner pt. from changed
D. R. pt. = corr'd obs'd alt. – comp'd alt. = – 13′ or 13 miles
Bearing of Sumner pt. from changed D. R. pt. = 99°,
since comp'd alt. is greater than obs'd alt.
Dist. 13, on course 99°, gives lat. diff., 2′.0; dep., 12.8; long. diff., 15′.9
Lat. of Sumner pt. = lat. of ch'd D. R. pt. + lat. diff. = – 35° 51′
Long. of Sumner pt. = long. of ch'd D. R. pt. + long. diff. = 20° 35′ E.

To complete this part of our subject, it remains to show how the position of the ship can be found at the intersection of two Sumner lines (pp. 111, 125) resulting from two different observations. Figure 18 explains the nature of the problem; and it is almost exactly the same figure and

[1] Q_2 being larger than the Greenwich hour-angle, the latter was increased by 360°, to make the subtraction possible (p. 128).

problem treated in Chapter V, when we discussed fixing a ship's position by means of "bearings from the bow" (p. 54).

The two Sumner lines in Fig. 18 are SL and $S'L$, passing through the two Sumner points S and S', whose latitudes and longitudes are known by calculation from the observed altitudes. The bearings or azimuths of the two Sumner lines from the north are the two angles NSL and $N'S'L$, which are also known from the previous calculations. It is now required to find the latitude and longitude of the intersection point L, where the ship is situated.

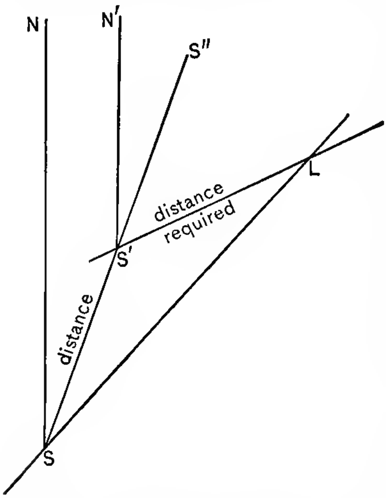

FIG. 18. — Intersection of Sumner Lines.

The similarity of this problem to the former one in Chapter V becomes plain, if we imagine a second ship sailing from one Sumner point to the other, as from S to S', and taking bearings from her bow upon *our* ship, located at L. These bearings will be the two angles $S'SL$ and $S''S'L$. If the second of these angles should happen to be just twice as big as the first, the distance $S'L$ between the two ships at the time of the second bearing would be equal (p. 54) to the distance SS' run by the imagined ship between the two observations.

This would enable us to fix the position of the imagined ship at S', if L were a lighthouse ashore. But if L is our ship, and S' a Sumner point of known position, the same observations of bow bearings would fix the position of our ship at L. Nor is it necessary (or possible) to measure

such imaginary bearings, or read the patent log to get the distance run by an imagined ship.

For the distance and bearing of the second Sumner point from the first can be obtained from their known latitudes and longitudes with the traverse table. Thus the line SS' (marked "distance") and the bearing (or course) angle NSS' become known. Furthermore, the "bow bearing" at S is the angle $S'SL$, and it is equal to the difference $NSL - NSS'$. We have just seen that NSS' is obtained from the traverse table; and NSL is the calculated azimuth of the Sumner line through S. In a similar way we get the other "bow bearing" $S''S'L$. If this were twice the first one, the "required distance" $S'L$ in the figure would be equal to the known distance SS' between the two Sumner points. If not, it can be easily shown mathematically that:

(1) Required distance = known distance $\times$ a factor,
(2) log factor = $\sin S'SL - \sin (S''S'L - S'SL)$.

By these simple formulas the required distance $S'L$ might be found: and as we also know the latitude and longitude of the Sumner point S', and the azimuth or bearing of $S'L$, the traverse table will make known the latitude and longitude of the ship at L. It is to be noted also that as we are at liberty to call either of the Sumner points S', it is desirable to call that one S' which has the larger "bow bearing," so that there will be no difficulty about subtracting $S'SL$ from $S''S'L$.

The factor of formula (2) above can practically always be found in our Table 14, the Sumner Intersection Table, without using logarithms. The pair of arguments of the table are the smaller "bow bearing" and the larger "bow bearing"; the tabular number is the factor of formula (1) above, and will always give the distance of the intersection point from that one of the two Sumner points for which the bow bearing was the larger.

And it should not be forgotten that the Sumner line really

extends equally in both directions (p. 124) from the Sumner point, whereas, in Fig. 18, we have extended it mainly in the direction of the intersection point L. Now the calculated azimuth of any Sumner line may be changed 180° at will, because the bearings of the two ends of the line from the Sumner point differ by 180°, and we may take the bearing of the line to be the bearing of either end from the Sumner point in the middle of the line. Figure 18 shows, however, that for the purpose of the present problem we must choose the bearing of that end of the line which is nearest the point of intersection L; nor does the choice ever offer difficulty, because the known D. R. position of the ship at L, when compared with the known positions of the two Sumner points, will always indicate whether L bears east or west of either Sumner point, and also whether it bears north or south. And the bearing of L once chosen, we can always find either of the two bow bearings by this formula:

(3) Bow bearing = bearing of Sumner line *minus* bearing of the second Sumner point S' from the first point S.

In using formula (3) it is allowable to increase the bearings of the Sumner lines by 360°, when necessary to make the subtractions possible, and if the formula brings out bow bearings larger than 180°, subtract them from 360°, and proceed as before.

It is also always desirable to draw a rough sketch for every intersection problem occurring on shipboard so as to guard against accidental large errors like 90° or 180° in obtaining the two bow bearings; and also to make sure that the latitude and longitude of the intersection point L are correctly computed with the traverse table.

The foregoing assumes that the ship did not move from the point L between the two sextant observations from which the two Sumner lines were calculated. This will rarely be the case, because it is very desirable that the two observations, if they are both sun observations, be separated by

three or four hours, if possible. The condition of an unmoving ship will occur only if she is a sailing vessel becalmed, or a steamer at anchor; or if the two observations are made at nearly the same time upon two different heavenly bodies, such as two stars.

High accuracy in the resulting "fix" (p. 53) of the ship will then be attained, if the azimuths of the two stars differ by about 90° at the time of observation. The same favorable condition will be secured if one of the observations is made upon a star near upper transit (pp. 89, 96), in the twilight just before sunrise or after sunset; and the other observation, at nearly the same time, upon the sun, when it is about 12° or 15° above the horizon.

But if the ship has traveled a considerable distance between the two observations, it is necessary to allow for such travel before calculating the intersection point. Suppose she has gone a distance D, upon a course C, by D. R., between the two observations. Then simply find from Tables 1 and 2 the difference of latitude and longitude corresponding to distance D and course C; and apply them as corrections to the latitude and longitude of the Sumner point belonging to the first observation. Everything else, including the bearing of the first Sumner line, remaining unchanged, the calculation then proceeds by Table 14, just as if the ship had not moved. The computed intersection point is then the ship's position at the time of the second sextant observation.

We shall now work some intersection examples.

Suppose we have two Sumner lines, as shown in the rough sketch, Fig. 19, taken on board a ship becalmed. The two sextant observations give:

	For One Sumner Point, S	For the Other Point, S'
lat.[1]:	42° 34′ N.	42° 50′ N.
long.:	35° 50′ W.	35° 36′ W.
bearing of Sumner line:	307°	93° (changed to 273°)

[1] As found on page 132.

The rough sketch, Fig. 19, having been made, and the two "bow bearings" marked with little circular arcs as shown, we call that one of the two Sumner points S', which has the larger bow bearing; and, for the point S', we change

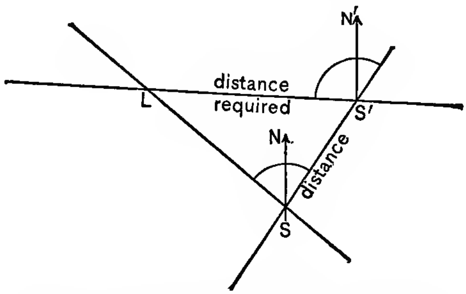

FIG. 19.—Rough Sketch of Sumner Intersection.

the bearing of the Sumner line from 93° to 180° + 93° = 273°, so as to count the bearing for that end of the line which is toward the intersection point L (p. 136). The other bearing, 307°, for the point S, is already correctly counted.

We now have, from the two Sumner point latitudes and longitudes: latitude difference = 16′; longitude difference = 14′; departure (Table 2, p. 174, for middle latitude 43°) = 10.2; and, for latitude difference = 16, departure = 10.2, we find (Table 1, p. 162), distance = 19, course = 32°. The distance between the two Sumner points is therefore 19 miles, and the bearing of S' from S is 32°.

Now we apply formula (3), page 136, and find:

Smaller bow bearing at S = 307° − 32° = 275°.
Larger bow bearing at S' = 273° − 32° = 241°.

Being larger than 180°, these must be subtracted from 360° (p. 136), giving:

Smaller bow bearing = 85°; Larger bow bearing = 119°.

Next we refer to Table 14, and find with the smaller bearing 85°, and the larger 119° the factor 1.78 (p. 322).

According to formula (1), page 135, we then have:
Required distance $LS' =$ distance $SS' \times$ factor
$= 19 \times 1.78 = 33.8$ miles.

Therefore the position of the ship at L is distant 33.8 miles from S', and she bears 273°. With this distance and bearing or course angle, the traverse table (p. 154) gives: latitude = 1.8, departure = 33.8. For the departure 33.8, Table 2 gives, for the middle latitude 43° (p. 174), difference longitude = 46′.2. The bearing 273° showing that the intersection point L is N. and W. of S', we have:

Latitude of ship at L = 42° 50′ N. + 1′.8 = 42° 51′.8 N.
Longitude of ship at L = 35° 36′ W. + 46′.2 = 36° 22′ W.

As a second example take the following two Sumner lines, as shown in the rough sketch, Fig. 20. The two sextant observations give:

	For One Sumner Point, S	For the Other Point, S'
lat.:	14° 26′ N.	15° 30′ N.
long.:	77° 8′ W.	76° 22′.5 W.
bearing of line:	53°	135°

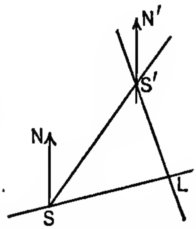

Fig. 20.—Rough Sketch of Sumner Intersection.

And suppose the ship, in the interval between the two sextant observations, has traveled a distance $D = 31$ miles, on course $C = 205°$. We must begin (p. 137) by shifting the first Sumner point S a distance D, on the course C. For this course and distance, we have (Table 1, p. 160): lat., 28′.1; dep., 13.1; diff. long., 13′.5 (Table 2, p. 168).

Therefore, the latitude and longitude of the first Sumner point must be corrected (p. 137) as follows:

For the point S, lat. = 14° 26′ N. − 28′.1 = 13° 58′ N.
long. = 77° 8′ W. + 13′.5 = 77° 21′.5 W.

Bearing (unchanged) = 53°.

We now have, for the two Sumner points: lat. diff., 92′;

long. diff., 59′; dep., 57.0 (p. 169); dist., 108 miles (p. 162); bearing of S' from S, 32°.

Now we have, by formula (3), page 136:

$$\text{Smaller bow bearing at } S = 53° - 32° = 21°.$$
$$\text{Larger bow bearing at } S' = 135° - 32° = 103°.$$

Table 14 (p. 319) gives the factor 0.36; so that the ship at L is distant from S' $108 \times .36 = 38.9$ miles, and bears 135°. For this distance and bearing we have (Table 1, p. 166), latitude = 27′.6; departure = 27.6; and longitude difference (Table 2, p. 168) = 28′.6. Finally, then, at the time of the second sextant observation, the ship at L was in latitude 15° 30′ N. − 27′.6 = 15° 2′.4 N.; and in longitude 76° 22′.5 W. − 28′.6 = 75° 54′ W.

CHAPTER X

A NAVIGATOR'S DAY AT SEA

THE present chapter contains a number of examples by means of which the reader can gain facility in the use of the methods set forth in the preceding pages.

The steam yacht *Nav* is bound from New York to Colon, and the captain plans to take his departure from the Sandy Hook Lightship, on Dec. 18, 1917, as early as possible in the morning.

The first bit of navigation, to be accomplished before the yacht leaves her anchorage in the "Horseshoe," is to ascertain by D. R. methods the proper course to steer from Sandy Hook. A glance at the track chart of the north Atlantic shows that she must go by way of Crooked Island Passage, and the Windward Passage between Cuba and Haiti. It is also apparent from the chart that the first land to be sighted among the islands is Watlings Island, and that the proper course should pass to the eastward of it.

The position of Sandy Hook Lightship [1] is lat. 40° 28′ N.; long. 73° 50′ W. Hinchinbroke Rock, at the southern end of Watlings Island, is in lat. 23° 57′ N.; long. 74° 28′ W. But the course should be shaped for a point about 12 miles east of Watlings Island, to be perfectly safe. The position of such a point is (approximately) lat. 23° 57′ N.; long. 74° 15′ W.[2]

[1] There is an excellent list of latitudes and longitudes in Bowditch's "Navigator."

[2] The difference between this longitude and that of Hinchinbroke Rock is 13′; but 13′ here corresponds to about 12 miles, on account of Table 2.

ABSTRACT OF LOG. Steam Yacht *Nav*, Dec. 18, 1917

		Patent Log	Compass Course	True Course
7:02 A.M.	Took departure from Sandy Hook Lightship.........	26.2	S.	188°
7:21	Sunrise, observed azimuth	31.0	S.	188°
8:00		41.0	S.	188°
9:00		57.2	S.	188°
9:36	Bow bearing, Barnegat....	67.0	S.	188°
9:42	Altitude and azimuth......	69.1	S.	188°
9:57	Beam bearing, Barnegat... (fix, lat. 39° 45′ N.; long. 73° 59′ W.)	72.5	S.	188°
10:00		73.4	S.	188°
10:07	Changed course...........	75.3	S.½E.	182°
11:00		88.7	S.½E.	182°
11:42	Ex-mer. obs'n lat. 39° 19′; D. R. long. 73° 58′	98.5	S.½E.	182°
12:00		102.6	S.½E.	182°
1:00 P.M.		117.7	S.½E.	182°
2:00		133.0	S.½E.	182°
3:00		149.0	S.½E.	182°
4:00		163.8	S.½E.	182°
4:12	Alt. and az., fix, lat. 38° 11′; long. 73° 54′	166.9	S.½E.	182°
5:00		182.0	S.½E.	182°
6:00		197.2	S.¾E.	182½°

By the method of page 20, the course from Sandy Hook Lightship should be 181°, and the distance is 990 miles. These numbers, and all subsequent numbers in the present chapter, should be verified by the reader.

The distance being quite large, it is well to check it by the logarithmic method, page 33. The result by this method is: course 181° 14′, distance 991.7 miles.

The chart also shows that this course will carry the yacht very near Barnegat Light, on the coast of New Jersey. The position of this light is lat. 39° 46′ N.; long. 74° 6′ W. The captain decides that it will be well to plan passing this light

at about 5 miles' distance. The position of a point 5 miles east of Barnegat Light is lat. 39° 46′ N., long. 73° 59′ W. The course and distance to this point from Sandy Hook Ship are 189° and 42.5 miles. This course is so nearly the same as the course to Watlings Island that the captain decides to steer the 189° course.

All this work must be complete before reaching Sandy Hook, for the course from the lightship must be ready for the quartermaster before the lightship is passed. And there is still more preliminary work. For the courses calculated above are true courses (p. 43) and the quartermaster must have the compass course, so that he may be able to steer the yacht. The method of calculating the compass course from the true course is given on page 48; and in applying it the captain must have his deviation tables at hand. We shall assume that the tables printed on pages 48 and 49 were the ones furnished by the compass adjuster for the present voyage.

An examination of the Atlantic track chart shows that in the vicinity of Sandy Hook, the variation, V, is 10° W., or $-10°$. By formula (3) (p. 49), we then have, since the true course T is 189°:

$$\text{Magnetic course} = M = T - V = 189° - (-10°) = 199°.$$

The second deviation table (p. 49) shows that when the magnetic course (or magnetic bearing of ship's head) is 199°, the deviation, D, is $+18°$. Then, with $V = -10°, D = 18°$, formula (1), page 45, gives:

$$\text{Compass error} = E = V + D = -10° + 18° = +8°.$$

And from formula (2), page 45:

$$\text{Compass course } C = T - E = 189° - 8° = 181°;$$

and so the yacht must be steered on a 181° compass course for Barnegat. But the quartermaster is to steer by "points" so that the course nearest the 181° course is due south. The captain decides to have the yacht steered due south by

compass, and is prepared to give the quartermaster his orders as soon as Sandy Hook Lightship shall be reached.

The foregoing preliminary work having been completed the previous day, the anchor is tripped at the Horseshoe about an hour before daylight on Dec. 18, the weather being fine, sea smooth, and wind light from the northwest. The lightship is reached and passed at 7 : 02 A.M., ship's time, civil reckoning, the ship then taking her departure. At that moment, the patent log is read, and found to register 26.2 miles. The quartermaster gets his orders to steer south; and *all* the above facts are duly recorded in the log-book. And at every hour thereafter, 8, 9, 10, etc., a similar record must be made in the log-book.

The next event is sunrise, which occurs at 7 : 21, very soon after leaving the lightship. The sun's compass bearing can then be very conveniently observed, and will furnish an excellent check on the compass adjuster. This observation was made at 7 : 21 A.M., ship's time, civil reckoning, corresponding to $19^h\ 21^m$, Dec. 17, ship's apparent time, astronomic reckoning; and the sun's bearing or azimuth was 113° by compass. This was entered in the log-book, and at the same time the patent log was read, and found to be 31.0 miles.

To check the deviation table, the procedure was then as follows:

By patent log the yacht had proceeded from the lightship a distance of 31.0 − 26.2 = 4.8 miles, on a compass course of 180°, or true course of 188°; by D. R., she had therefore reached the position lat. 40° 23′ N.; long. 73° 51′ W. The sun's declination, from the almanac, is − 23° 23′, and the (approximate[1]) T (p. 100) is $19^h\ 21^m$. The sun's true azimuth is found from Table 11 to be 121°; and in using the table for this purpose take the altitude of the sun, for the

[1] If there is any chance of this T being much in error, the captain's watch, by which the observation is timed, must be compared with the chronometer. See p. 94.

moment of sunrise, to be 0°. The observed compass azimuth having been 113°, formula (2), page 45, gave $E = T - C = 121° - 113° = +8°$. Then from formula (1), page 45, $D = E - V = +8° - (-10°) = +18°$. As expected, this deviation agrees with the deviation table, which would not be likely to go wrong so soon after the beginning of a voyage.

At 8 A.M. the patent log read 41.0; and at 9 A.M., 57.2. The course was still S. by compass, or 188°, true course.

At 9:24 Barnegat Light was sighted by the lookout, and the mate was ordered to take bow-and-beam bearings (p. 55) upon it.

At 9:36, the light bore 225° by compass, or 45° from the bow; patent log, 67.0.

At $9^h\ 42^m\ 28^s$ by his watch the captain took the altitude of the sun's lower limb with the sextant, and found it to be 18° 51′. Index correction was + 3′, and height of eye, 15 feet. C. – W. was $4^h\ 51^m\ 50^s$; and the chr. correction by the rate card was 4^s, slow. Patent log, 69.1. At 9:45 by the watch, the sun's azimuth was again observed with pelorus, and found to be 137°, compass bearing. It was intended to work a Sumner line from the altitude by Kelvin's table; and the pelorus observation was made because the sun's true azimuth always comes out as a by-product, when Kelvin's table is used, and so it is just as well to have another check on the deviation table. This is the peculiar advantage of Kelvin's table. Without any additional calculations, the compass is always checked up on the very course the ship is steering. This is just what the good navigator wants.

The observations could not be worked up at once, because the captain wished to see the result of the mate's bow-and-beam bearings. At 9:57 by the watch, Barnegat bore abeam, on the starboard hand, or 270° by compass, the yacht being still on the 180° compass course. Patent log now 72.5.

Between the bow-and-beam bearings the run by log was 72.5 − 67 = 5.5 miles. Therefore the yacht is now 5.5 miles from Barnegat Light, and the compass bearing of the light is 270°. The compass error being + 8°, the true bearing of the light is 278°; and the bearing of the yacht from the light is the former bearing reversed, or 278° − 180° = 98°, true. From this comes an accurate and complete position of the yacht. Barnegat Light is in lat. 39° 46′ N.; long. 74° 6′ W. The yacht, 5.5 miles away on the bearing 98°, must, by traverse table, be in lat. 39° 45′ N.; long. 73° 59′ W.

At 10 A.M., the log was 73.4, course 188°, true.

Now the captain prepared to shape a new course to be followed from the Barnegat bow-and-beam bearing "fix" in the above lat. 39° 45′ N.; long. 73° 59′ W., at 9 : 57.

Allowing ten minutes to work up the new course, the captain plans to change course at 10 : 07. At that time the ship, on her course of 188°, will be (at 15-knot speed) 2′.5 S. and practically 0′ W. of the Barnegat position. So the course will be changed when the yacht is in lat. 39° 42′ N.; long. 73° 59′ W., at 10 : 07. The course and distance from there to the point 12 miles east of Hinchinbroke Rock are: distance, 945 miles; course, 181°, true, or 173° by compass.

Therefore, by the table on page 52, the quartermaster gets the new course S.½E. by compass, at 10 : 07. This corresponds to 174° by compass, or 182° true course; and at 10 : 07, when the course was changed, the patent log read 75.3.

Now the Sumner line, from the observation at $9^h\ 42^m\ 28^s$ by the watch, was worked by Kelvin's table; and the result was:

Sumner point is in lat. 39° 50′ N.; long. 73° 56′ W.; bearing of Sumner line 237°.

It is necessary, as a check, to ascertain whether this Sumner line passes through the position obtained for the ship by the Barnegat bearings. Before doing this, the Sumner point must be shifted by the method of page 137, to allow for

the motion of the yacht between 9:42, when the sextant observation was made, and 9:57, when Barnegat bore abeam. The difference is 15 minutes, and in that time the ship moved south 3.4 miles by the patent log and an insignificant distance west.

Therefore the corrected Sumner data are:

Sumner point is in lat. 39° 46′.6 N.; long. 73° 56′ W.; bearing of Sumner line 237°.

If everything fits, this Sumner line must pass through the Barnegat "fix" of the yacht in lat. 39° 45′ N.; long. 73° 59′ W., because the yacht must have been somewhere on the line.

The traverse table shows that the bearing of a line passing the Sumner point and the yacht's position is 235°, differing only 2° from the Sumner line bearing; so this check is satisfactory. But a better way to check this matter is to determine the yacht's position from the intersection of two lines, one of which is the Sumner line, and the other the beam bearing of Barnegat Light. This can be done by the method of page 133. The data of the problem are:

Sumner point: lat. 39° 46′.6 N.
long. 73° 56′ W.
Line bears 237°
Barnegat Light: lat. 39° 46′ N.
long. 74° 6′ W.
Line bears 98°

We shall call Barnegat Light S'; and then formula (3), page 136, gives, for the two bow bearings:

At Sumner point, S, $237° - 266° = 29°$.
At Barnegat, S', $98° - 266° = 168°$.

For these two bearings, Table 14 gives the factor 0.74, and the yacht is placed 6 miles from Barnegat, on the 98° bearing. The bow-and-beam observations gave 5.5 miles, so the check by the Sumner line is excellent.

It remains for the captain to utilize the azimuth observa-

tion made at 9 : 45. The bearing of the Sumner line was 237°, and therefore the sun's true azimuth was 147°. The observed azimuth, by pelorus (p. 145), was 137°. The compass error was therefore + 10°. The variation being − 10°, the deviation by formula (1), page 45, is $D = 10° - (-10°) = +20°$.

On page 143 we found that the deviation table made this deviation + 18°; so that the table appears to require a correction of + 2°. The captain decides not to correct the table for the present, unless later azimuth observations shall confirm it, especially as the sunrise observation showed the adjuster's results to be correct. Azimuth observations made when the sun is high in the sky are not quite as reliable as sunrise ones. Moreover, the observation was made at 9 : 45, whereas the altitude observation, for which the true azimuth was calculated with Kelvin's table, was made at 9 : 42, so that the true azimuth must have been in error by the sun's azimuth change in three minutes. This could have been avoided by giving the mate orders to observe the azimuth at about the same moment when the captain took the altitude. Or, the sun's azimuth change in three minutes might be taken from the azimuth table, and the computed true azimuth duly corrected.

At 11 the log read 88.7, and the course was S.½E. by compass, or 182°, true.

At about 11 : 30, the weather showing signs of becoming thick, no preparations were made for a noon-sight by the method of page 86; and rather than take the risk of losing his noon observation altogether, the captain took an ex-meridian altitude at $11^h\ 42^m\ 0^s$ by his watch; log was 98.5; the sextant reading 26° 55′; index + 3′; height of eye 15 ft.; C. − W. was now $4^h\ 51^m\ 42^s$; and chronometer slow 4^s.

The observation was worked by Kelvin's table, and gave the Sumner point in lat. 39° 20′ N.; long. 73° 40′ W.; bearing of Sumner line 86°. Figure 21 is a rough sketch of this Sumner line. It is very nearly horizontal; had the observation been

made at noon precisely, it would have been perfectly horizontal.

It would now have been possible to move up the Sumner line observed at 9 : 42, and obtain an intersection to fix the position of the yacht. But this did not seem necessary to the captain, because of the beam bearing obtained at Barnegat at 9 : 57, which gave a good fix.

And the present Sumner line being so nearly horizontal, it is not necessary to know the longitude very accurately to obtain an exact latitude. The longitude by D. R. is sufficient, and it is 73° 58′ W. The difference between this longitude and that of the Sumner point (73° 40′) is 18′; and the ship at *L* (fig. 21) bears 180° + 86° = 266° from the Sumner point. Table 2 gives the dep. 14.0 for long. diff. 18′, in lat. 39°. And for course 266°, dep. 14.0, we find in Table 1, lat. diff. 1′.0, so the yacht's latitude is 1′ less than that of the Sumner point, and is therefore 39° 19′. This happens to be in exact accord with the D. R. latitude, which was also 39° 19′. This was perfectly satisfactory, and the captain decided to carry this Sumner line forward for an intersection, in case he should obtain an observation in the afternoon.

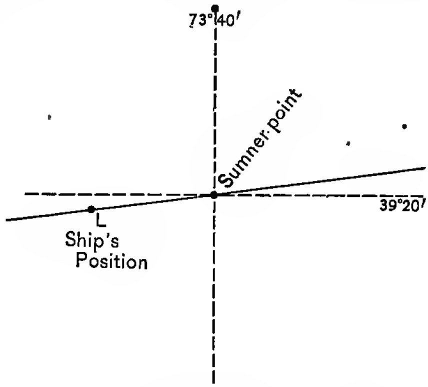

FIG. 21.—Sumner Line from ex-Meridian Observation.

At 12, the patent log read 102.6, course S.½E., 182° true; D. R. lat. 39° 15′; long. 73° 58′; distance to Watlings Island 918 miles.

Had the yacht been on a course other than almost due south, it would have been necessary to set the watch and the

cabin clock to ship's apparent time. In fact, some navigators set their watches to ship's apparent time before every observation (p. 94):

at 1, log read 117.7, misty,
at 2, log read 133.0, misty,
at 3, log read 149.0 misty,
at 4, log read 163.8, clearing.

At $4^h\ 12^m\ 18^s$ by the watch, the weather having cleared, the altitude of the sun was found to be 4° 38′; index + 4′; eye 15 ft.; C. − W. $4^h\ 51^m\ 50^s$; chronometer slow 4^s; log 166.9. Sun's azimuth, observed by the mate at the same time, came out 224° by compass.

This observation was worked for a Sumner line by the Kelvin table, and gave:

Position of Sumner point lat. 38° 6′ N.; long. 73° 49′ W.; bearing of line 145°; azimuth of sun 235°.

The Sumner line obtained at $11^h\ 42^m\ 0^s$ was brought up to the time of the present observation by D. R. (p. 137), giving: position of 11:42 Sumner point, after moving it, lat. 38° 12′ N.; long. 73° 43′ W.; bearing of the line 86°. Both lines were then sketched, as shown in Fig. 22. The point S is the (moved) Sumner point from the 11:42 observation, S' that from the 4:12 observation. The intersection point L is the position of the ship at 4:12, and it came out (p. 134): lat. 38° 11′ N.; long. 73° 54′ W. The position brought up by D. R. from 11:42 was: lat. 38° 11′; long. 74° 1′; so that there has been an easterly set of the current, amounting to 7′ of longitude in $4\frac{1}{2}$ hours. The sun's true azimuth at 4:12 was 235°, from the Kelvin table; and the pelorus observation gave 224°. The compass error was therefore

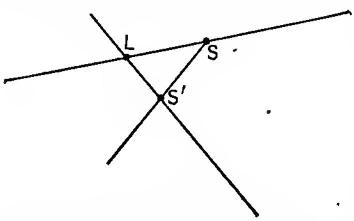

FIG. 22.—Rough Sketch of Sumner Line Intersection.

$+ 11°$. The variation being $- 10°$, the deviation must be $D = 11° - (- 10° =) + 21°$. The deviation table made this deviation $+ 18°$, so that table seems to require a correction of $+ 3°$. The pelorus observation of 9 : 45 gave a correction of $+ 2°$ for the deviation table; and as this is now apparently confirmed, the captain decides to examine the chart again, before finally shaping course for the night, to see if the yacht has not perhaps moved into a region where the variation is different from the Sandy Hook variation so far used.

At 5 the log read 182.0, course was still 182° true.

The captain now prepared to shape the course for the night, and to change his course, if necessary, at 6 : 00. His first step was to obtain the D. R. position at 6 : 00, starting from the observed position at 4 : 12. This gave position at 6 : 00, by D. R.: lat. 37° 41′; long. 73° 55′. The easterly current[1] of about 2′ per hour set the yacht farther east about 3′ between 4 : 12 and 6 : 00. Therefore he took the D. R. position at 6 : 00 to be lat. 37° 41′; long. 73° 52′. The position of the point of destination, 12 miles east of Watlings Island, is still: lat. 23° 57′; long. 74° 15′. The true course and distance to that point from the yacht's 6 : 00 position is therefore, by traverse table: course $181\frac{1}{2}°$; dist. 824 miles.

A further examination of the track chart shows that the variation, which was $- 10°$ at Sandy Hook, is now $- 8°$. The compass error, from the last pelorus observation, was $+ 11°$. Consequently, by the pelorus observation, the compass course for the night should be $181\frac{1}{2}° - 11° = 170\frac{1}{2}°$, or S.$\frac{3}{4}$E. (see the Table on p. 52). Furthermore, the variation being now $- 8°$ and the error $+ 11°$ makes the deviation $D = E - V = + 11° - (- 8°) = + 19°$. The compass adjuster's deviation of $+ 18°$ is therefore vindicated, and the compass course S.$\frac{3}{4}$E. can be set for the night.

At 6 the log read 197.2, course S.$\frac{3}{4}$E., or $182\frac{1}{2}°$ true.

[1] Doubtless the Gulf Stream.

In conclusion, the captain of the *Nav* hopes he has been able to make his imagined proceedings clear enough to help the young navigator in planning his own first day's work at sea. May it be the first of many happy and successful days. And let him not forget, when attempting to verify the various calculations and problems of the *Nav*, that every observation in this book has been prepared by calculation, and none is the result of actual sextant observing. Should inconsistencies or errors be found by any young navigator, it is hoped that he will make them known so that they may be corrected, in case the *Nav* shall be required to make another voyage in a second edition.

LIST OF TABLES

PUBLISHERS' NOTE

Table 3, Number Logarithms, has been reprinted from "The Macmillan Logarithmic and Trigonometric Tables," New York, 1917.

Dist.	1° (179°, 181°, 359°)		2° (178°, 182°, 358°)		¼ Pt. 3° (177°, 183°, 357°)		4° (176°, 184°, 356°)		5° (175°, 185°, 355°)		½ Pt. 6° (174°, 186°, 354°)		7° (173°, 187°, 353°)	
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.
1	1.0	0.0	1.0	0.0	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1	1.0	0.1
2	2.0	0.0	2.0	0.1	2.0	0.1	2.0	0.1	2.0	0.2	2.0	0.2	2.0	0.2
3	3.0	0.1	3.0	0.1	3.0	0.2	3.0	0.2	3.0	0.3	3.0	0.3	3.0	0.4
4	4.0	0.1	4.0	0.1	4.0	0.2	4.0	0.3	4.0	0.3	4.0	0.4	4.0	0.5
5	5.0	0.1	5.0	0.2	5.0	0.3	5.0	0.3	5.0	0.4	5.0	0.5	5.0	0.6
6	6.0	0.1	6.0	0.2	6.0	0.3	6.0	0.4	6.0	0.5	6.0	0.6	6.0	0.7
7	7.0	0.1	7.0	0.2	7.0	0.4	7.0	0.5	7.0	0.6	7.0	0.7	6.9	0.9
8	8.0	0.1	8.0	0.3	8.0	0.4	8.0	0.6	8.0	0.7	8.0	0.8	7.9	1.0
9	9.0	0.2	9.0	0.3	9.0	0.5	9.0	0.6	9.0	0.8	9.0	0.9	8.9	1.1
10	10.0	0.2	10.0	0.3	10.0	0.5	10.0	0.7	10.0	0.9	9.9	1.0	9.9	1.2
11	11.0	0.2	11.0	0.4	11.0	0.6	11.0	0.8	11.0	1.0	10.9	1.1	10.9	1.3
12	12.0	0.2	12.0	0.4	12.0	0.6	12.0	0.8	12.0	1.0	11.9	1.3	11.9	1.5
13	13.0	0.2	13.0	0.5	13.0	0.7	13.0	0.9	13.0	1.1	12.9	1.4	12.9	1.6
14	14.0	0.2	14.0	0.5	14.0	0.7	14.0	1.0	13.9	1.2	13.9	1.5	13.9	1.7
15	15.0	0.3	15.0	0.5	15.0	0.8	15.0	1.0	14.9	1.3	14.9	1.6	14.9	1.8
16	16.0	0.3	16.0	0.6	16.0	0.8	16.0	1.1	15.9	1.4	15.9	1.7	15.9	1.9
17	17.0	0.3	17.0	0.6	17.0	0.9	17.0	1.2	16.9	1.5	16.9	1.8	16.9	2.1
18	18.0	0.3	18.0	0.6	18.0	0.9	18.0	1.3	17.9	1.6	17.9	1.9	17.9	2.2
19	19.0	0.3	19.0	0.7	19.0	1.0	19.0	1.3	18.9	1.7	18.9	2.0	18.9	2.3
20	20.0	0.3	20.0	0.7	20.0	1.0	20.0	1.4	19.9	1.7	19.9	2.1	19.9	2.4
21	21.0	0.4	21.0	0.7	21.0	1.1	20.9	1.5	20.9	1.8	20.9	2.2	20.8	2.6
22	22.0	0.4	22.0	0.8	22.0	1.2	21.9	1.5	21.9	1.9	21.9	2.3	21.8	2.7
23	23.0	0.4	23.0	0.8	23.0	1.2	22.9	1.6	22.9	2.0	22.9	2.4	22.8	2.8
24	24.0	0.4	24.0	0.8	24.0	1.3	23.9	1.7	23.9	2.1	23.9	2.5	23.8	2.9
25	25.0	0.4	25.0	0.9	25.0	1.3	24.9	1.7	24.9	2.2	24.9	2.6	24.8	3.0
26	26.0	0.5	26.0	0.9	26.0	1.4	25.9	1.8	25.9	2.3	25.9	2.7	25.8	3.2
27	27.0	0.5	27.0	0.9	27.0	1.4	26.9	1.9	26.9	2.4	26.9	2.8	26.8	3.3
28	28.0	0.5	28.0	1.0	28.0	1.5	27.9	2.0	27.9	2.4	27.8	2.9	27.8	3.4
29	29.0	0.5	29.0	1.0	29.0	1.5	28.9	2.0	28.9	2.5	28.8	3.0	28.8	3.5
30	30.0	0.5	30.0	1.0	30.0	1.6	29.9	2.1	29.9	2.6	29.8	3.1	29.8	3.7
31	31.0	0.5	31.0	1.1	31.0	1.6	30.9	2.2	30.9	2.7	30.8	3.2	30.8	3.8
32	32.0	0.6	32.0	1.1	32.0	1.7	31.9	2.2	31.9	2.8	31.8	3.3	31.8	3.9
33	33.0	0.6	33.0	1.2	33.0	1.7	32.9	2.3	32.9	2.9	32.8	3.4	32.8	4.0
34	34.0	0.6	34.0	1.2	34.0	1.8	33.9	2.4	33.9	3.0	33.8	3.6	33.7	4.1
35	35.0	0.6	35.0	1.2	35.0	1.8	34.9	2.4	34.9	3.1	34.8	3.7	34.7	4.3
36	36.0	0.6	36.0	1.3	36.0	1.9	35.9	2.5	35.9	3.1	35.8	3.8	35.7	4.4
37	37.0	0.6	37.0	1.3	36.9	1.9	36.9	2.6	36.9	3.2	36.8	3.9	36.7	4.5
38	38.0	0.7	38.0	1.3	37.9	2.0	37.9	2.7	37.9	3.3	37.8	4.0	37.7	4.6
39	39.0	0.7	39.0	1.4	38.9	2.0	38.9	2.7	38.9	3.4	38.8	4.1	38.7	4.8
40	40.0	0.7	40.0	1.4	39.9	2.1	39.9	2.8	39.8	3.5	39.8	4.2	39.7	4.9
41	41.0	0.7	41.0	1.4	40.9	2.1	40.9	2.9	40.8	3.6	40.8	4.3	40.7	5.0
42	42.0	0.7	42.0	1.5	41.9	2.2	41.9	2.9	41.8	3.7	41.8	4.4	41.7	5.1
43	43.0	0.8	43.0	1.5	42.9	2.3	42.9	3.0	42.8	3.7	42.8	4.5	42.7	5.2
44	44.0	0.8	44.0	1.5	43.9	2.3	43.9	3.1	43.8	3.8	43.8	4.6	43.7	5.4
45	45.0	0.8	45.0	1.6	44.9	2.4	44.9	3.1	44.8	3.9	44.8	4.7	44.7	5.5
46	46.0	0.8	46.0	1.6	45.9	2.4	45.9	3.2	45.8	4.0	45.7	4.8	45.7	5.6
47	47.0	0.8	47.0	1.6	46.9	2.5	46.9	3.3	46.8	4.1	46.7	4.9	46.6	5.7
48	48.0	0.8	48.0	1.7	47.9	2.5	47.9	3.3	47.8	4.2	47.7	5.0	47.6	5.8
49	49.0	0.9	49.0	1.7	48.9	2.6	48.9	3.4	48.8	4.3	48.7	5.1	48.6	6.0
50	50.0	0.9	50.0	1.7	49.9	2.6	49.9	3.5	49.8	4.4	49.7	5.2	49.6	6.1
100	100.0	1.7	99.9	3.5	99.9	5.2	99.8	7.0	99.6	8.7	99.5	10.5	99.3	12.2
200	200.0	3.5	199.9	7.0	199.7	10.5	199.5	14.0	199.2	17.4	198.9	20.9	198.5	24.4
300	300.0	5.2	299.8	10.5	299.6	15.7	299.3	20.9	298.9	26.1	298.4	31.4	297.8	36.6
400	399.9	7.0	399.8	13.9	399.4	20.9	399.0	27.9	398.5	34.9	397.8	41.8	397.0	48.7
500	499.9	8.8	499.7	17.4	499.3	26.2	498.8	34.8	498.1	43.6	497.3	52.3	496.3	61.0
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.
	(91°, 269°, 271°) 89°		(92°, 268°, 272°) 88°		(93°, 267°, 273°) 7¾ Pt. 87°		(94°, 266°, 274°) 86°		(95°, 265°, 275°) 85°		(96°, 264°, 276°) 7½ Pt. 84°		(97°, 263°, 277°) 83°	

Dist.	1° (179°, 181°, 359°)		2° (178°, 182°, 358°)		¼ Pt. 3° (177°, 183°, 357°)		4° (176°, 184°, 356°)		5° (175°, 185°, 355°)		½ Pt. 6° (174°, 186°, 354°)		7° (173°, 187°, 353°)	
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.
51	51.0	0.9	51.0	1.8	50.9	2.7	50.9	3.6	50.8	4.4	50.7	5.3	50.6	6.2
52	52.0	0.9	52.0	1.8	51.9	2.7	51.9	3.6	51.8	4.5	51.7	5.4	51.6	6.3
53	53.0	0.9	53.0	1.8	52.9	2.8	52.9	3.7	52.8	4.6	52.7	5.5	52.6	6.5
54	54.0	0.9	54.0	1.9	53.9	2.8	53.9	3.8	53.8	4.7	53.7	5.6	53.6	6.6
55	55.0	1.0	55.0	1.9	54.9	2.9	54.9	3.8	54.8	4.8	54.7	5.7	54.6	6.7
56	56.0	1.0	56.0	2.0	55.9	2.9	55.9	3.9	55.8	4.9	55.7	5.9	55.6	6.8
57	57.0	1.0	57.0	2.0	56.9	3.0	56.9	4.0	56.8	5.0	56.7	6.0	56.6	6.9
58	58.0	1.0	58.0	2.0	57.9	3.0	57.9	4.0	57.8	5.1	57.7	6.1	57.6	7.1
59	59.0	1.0	59.0	2.1	58.9	3.1	58.9	4.1	58.8	5.1	58.7	6.2	58.6	7.2
60	60.0	1.0	60.0	2.1	59.9	3.1	59.9	4.2	59.8	5.2	59.7	6.3	59.6	7.3
61	61.0	1.1	61.0	2.1	60.9	3.2	60.9	4.3	60.8	5.3	60.7	6.4	60.5	7.4
62	62.0	1.1	62.0	2.2	61.9	3.2	61.8	4.3	61.8	5.4	61.7	6.5	61.5	7.6
63	63.0	1.1	63.0	2.2	62.9	3.3	62.8	4.4	62.8	5.5	62.7	6.6	62.5	7.7
64	64.0	1.1	64.0	2.2	63.9	3.3	63.8	4.5	63.8	5.6	63.6	6.7	63.5	7.8
65	65.0	1.1	65.0	2.3	64.9	3.4	64.8	4.5	64.8	5.7	64.6	6.8	64.5	7.9
66	66.0	1.2	66.0	2.3	65.9	3.5	65.8	4.6	65.7	5.8	65.6	6.9	65.5	8.0
67	67.0	1.2	67.0	2.3	66.9	3.5	66.8	4.7	66.7	5.8	66.6	7.0	66.5	8.2
68	68.0	1.2	68.0	2.4	67.9	3.6	67.8	4.7	67.7	5.9	67.6	7.1	67.5	8.3
69	69.0	1.2	69.0	2.4	68.9	3.6	68.8	4.8	68.7	6.0	68.6	7.2	68.5	8.4
70	70.0	1.2	70.0	2.4	69.9	3.7	69.8	4.9	69.7	6.1	69.6	7.3	69.5	8.5
71	71.0	1.2	71.0	2.5	70.9	3.7	70.8	5.0	70.7	6.2	70.6	7.4	70.5	8.7
72	72.0	1.3	72.0	2.5	71.9	3.8	71.8	5.0	71.7	6.3	71.6	7.5	71.5	8.8
73	73.0	1.3	73.0	2.5	72.9	3.8	72.8	5.1	72.7	6.4	72.6	7.6	72.5	8.9
74	74.0	1.3	74.0	2.6	73.9	3.9	73.8	5.2	73.7	6.4	73.6	7.7	73.4	9.0
75	75.0	1.3	75.0	2.6	74.9	3.9	74.8	5.2	74.7	6.5	74.6	7.8	74.4	9.1
76	76.0	1.3	76.0	2.7	75.9	4.0	75.8	5.3	75.7	6.6	75.6	7.9	75.4	9.3
77	77.0	1.3	77.0	2.7	76.9	4.0	76.8	5.4	76.7	6.7	76.6	8.0	76.4	9.4
78	78.0	1.4	78.0	2.7	77.9	4.1	77.8	5.4	77.7	6.8	77.6	8.2	77.4	9.5
79	79.0	1.4	79.0	2.8	78.9	4.1	78.8	5.5	78.7	6.9	78.6	8.3	78.4	9.6
80	80.0	1.4	80.0	2.8	79.9	4.2	79.8	5.6	79.7	7.0	79.6	8.4	79.4	9.7
81	81.0	1.4	81.0	2.8	80.9	4.2	80.8	5.7	80.7	7.1	80.6	8.5	80.4	9.9
82	82.0	1.4	82.0	2.9	81.9	4.3	81.8	5.7	81.7	7.1	81.6	8.6	81.4	10.0
83	83.0	1.4	82.9	2.9	82.9	4.3	82.8	5.8	82.7	7.2	82.5	8.7	82.4	10.1
84	84.0	1.5	83.9	2.9	83.9	4.4	83.8	5.9	83.7	7.3	83.5	8.8	83.4	10.2
85	85.0	1.5	84.9	3.0	84.9	4.4	84.8	5.9	84.7	7.4	84.5	8.9	84.4	10.4
86	86.0	1.5	85.9	3.0	85.9	4.5	85.8	6.0	85.7	7.5	85.5	9.0	85.4	10.5
87	87.0	1.5	86.9	3.0	86.9	4.6	86.8	6.1	86.7	7.6	86.5	9.1	86.4	10.6
88	88.0	1.5	87.9	3.1	87.9	4.6	87.8	6.1	87.7	7.7	87.5	9.2	87.3	10.7
89	89.0	1.6	88.9	3.1	88.9	4.7	88.8	6.2	88.7	7.8	88.5	9.3	88.3	10.8
90	90.0	1.6	89.9	3.1	89.9	4.7	89.8	6.3	89.7	7.8	89.5	9.4	89.3	11.0
91	91.0	1.6	90.9	3.2	90.9	4.8	90.8	6.3	90.7	7.9	90.5	9.5	90.3	11.1
92	92.0	1.6	91.9	3.2	91.9	4.8	91.8	6.4	91.6	8.0	91.5	9.6	91.3	11.2
93	93.0	1.6	92.9	3.2	92.9	4.9	92.8	6.5	92.6	8.1	92.5	9.7	92.3	11.3
94	94.0	1.6	93.9	3.3	93.9	4.9	93.8	6.6	93.6	8.2	93.5	9.8	93.3	11.5
95	95.0	1.7	94.9	3.3	94.9	5.0	94.8	6.6	94.6	8.3	94.5	9.9	94.3	11.6
96	96.0	1.7	95.9	3.4	95.9	5.0	95.8	6.7	95.6	8.4	95.5	10.0	95.3	11.7
97	97.0	1.7	96.9	3.4	96.9	5.1	96.8	6.8	96.6	8.5	96.5	10.1	96.3	11.8
98	98.0	1.7	97.9	3.4	97.9	5.1	97.8	6.8	97.6	8.5	97.5	10.2	97.3	11.9
99	99.0	1.7	98.9	3.5	98.9	5.2	98.8	6.9	98.6	8.6	98.5	10.3	98.3	12.1
100	100.0	1.7	99.9	3.5	99.9	5.2	99.8	7.0	99.6	8.7	99.5	10.5	99.3	12.2
600	599.9	10.5	599.6	20.9	599.2	31.4	598.6	41.9	597.7	52.3	596.7	62.7	595.5	73.1
700	699.8	12.2	699.5	24.4	699.0	36.6	698.2	48.8	697.2	61.0	696.1	73.2	694.9	85.3
800	799.8	14.0	799.5	27.9	798.9	41.9	798.0	55.8	796.9	69.7	795.6	83.6	794.1	97.5
900	899.7	15.7	899.3	31.4	898.6	47.1	897.6	62.8	896.4	78.4	895.0	94.1	893.3	109.6
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.
	(91°, 269°, 271°) 89°		(92°, 268° 272°) 88°		(93°, 267°, 273°) 7¾ Pt. 87°		(94°, 266°, 274°) 86°		(95°, 265°, 275°) 85°		(96°, 264°, 276°) 7½ Pt. 84°		(97°, 263°, 277°) 83°	

Dist.	¾ Pt. **8°** (172°, 188°, 352°)		**9°** (171°, 189°, 351°)		**10°** (170°, 190°, 350°)		1 Pt. **11°** (169°, 191°, 349°)		**12°** (168°, 192°, 348°)		**13°** (167°, 193°, 347°)		1¼ Pt. **14°** (166°, 194°, 346°)	
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.
1	1.0	0.1	1.0	0.2	1.0	0.2	1.0	0.2	1.0	0.2	1.0	0.2	1.0	0.2
2	2.0	0.3	2.0	0.3	2.0	0.3	2.0	0.4	2.0	0.4	1.9	0.4	1.9	0.5
3	3.0	0.4	3.0	0.5	3.0	0.5	2.9	0.6	2.9	0.6	2.9	0.7	2.9	0.7
4	4.0	0.6	4.0	0.6	3.9	0.7	3.9	0.8	3.9	0.8	3.9	0.9	3.9	1.0
5	5.0	0.7	4.9	0.8	4.9	0.9	4.9	1.0	4.9	1.0	4.9	1.1	4.9	1.2
6	5.9	0.8	5.9	0.9	5.9	1.0	5.9	1.1	5.9	1.2	5.8	1.3	5.8	1.5
7	6.9	1.0	6.9	1.1	6.9	1.2	6.9	1.3	6.8	1.5	6.8	1.6	6.8	1.7
8	7.9	1.1	7.9	1.3	7.9	1.4	7.9	1.5	7.8	1.7	7.8	1.8	7.8	1.9
9	8.9	1.3	8.9	1.4	8.9	1.6	8.8	1.7	8.8	1.9	8.8	2.0	8.7	2.2
10	9.9	1.4	9.9	1.6	9.8	1.7	9.8	1.9	9.8	2.1	9.7	2.2	9.7	2.4
11	10.9	1.5	10.9	1.7	10.8	1.9	10.8	2.1	10.8	2.3	10.7	2.5	10.7	2.7
12	11.9	1.7	11.9	1.9	11.8	2.1	11.8	2.3	11.7	2.5	11.7	2.7	11.6	2.9
13	12.9	1.8	12.8	2.0	12.8	2.3	12.8	2.5	12.7	2.7	12.7	2.9	12.6	3.1
14	13.9	1.9	13.8	2.2	13.8	2.4	13.7	2.7	13.7	2.9	13.6	3.1	13.6	3.4
15	14.9	2.1	14.8	2.3	14.8	2.6	14.7	2.9	14.7	3.1	14.6	3.4	14.6	3.6
16	15.8	2.2	15.8	2.5	15.8	2.8	15.7	3.1	15.7	3.3	15.6	3.6	15.5	3.9
17	16.8	2.4	16.8	2.7	16.7	3.0	16.7	3.2	16.6	3.5	16.6	3.8	16.5	4.1
18	17.8	2.5	17.8	2.9	17.7	3.1	17.7	3.4	17.6	3.7	17.5	4.0	17.5	4.4
19	18.8	2.6	18.8	3.0	18.7	3.3	18.7	3.6	18.6	4.0	18.5	4.3	18.4	4.6
20	19.8	2.8	19.8	3.1	19.7	3.5	19.6	3.8	19.6	4.2	19.5	4.5	19.4	4.8
21	20.8	2.9	20.7	3.3	20.7	3.6	20.6	4.0	20.5	4.4	20.5	4.7	20.4	5.1
22	21.8	3.1	21.7	3.4	21.7	3.8	21.6	4.2	21.5	4.6	21.4	4.9	21.3	5.3
23	22.8	3.2	22.7	3.6	22.7	4.0	22.6	4.4	22.5	4.8	22.4	5.2	22.3	5.6
24	23.8	3.3	23.7	3.8	23.6	4.2	23.6	4.6	23.5	5.0	23.4	5.4	23.3	5.8
25	24.8	3.5	24.7	3.9	24.6	4.3	24.5	4.8	24.5	5.2	24.4	5.6	24.3	6.0
26	25.7	3.6	25.7	4.1	25.6	4.5	25.5	5.0	25.4	5.4	25.3	5.8	25.2	6.3
27	26.7	3.8	26.7	4.2	26.6	4.7	26.5	5.2	26.4	5.6	26.3	6.1	26.2	6.5
28	27.7	3.9	27.7	4.4	27.6	4.9	27.5	5.3	27.4	5.8	27.3	6.3	27.2	6.8
29	28.7	4.0	28.6	4.5	28.6	5.0	28.5	5.5	28.4	6.0	28.3	6.5	28.1	7.0
30	29.7	4.2	29.6	4.7	29.5	5.2	29.4	5.7	29.3	6.2	29.2	6.7	29.1	7.3
31	30.7	4.3	30.6	4.8	30.5	5.4	30.4	5.9	30.3	6.4	30.2	7.0	30.1	7.5
32	31.7	4.5	31.6	5.0	31.5	5.6	31.4	6.1	31.3	6.7	31.2	7.2	31.0	7.7
33	32.7	4.6	32.6	5.2	32.5	5.7	32.4	6.3	32.3	6.9	32.2	7.4	32.0	8.0
34	33.7	4.7	33.6	5.3	33.5	5.9	33.4	6.5	33.3	7.1	33.1	7.6	33.0	8.2
35	34.7	4.9	34.6	5.5	34.5	6.1	34.4	6.7	34.2	7.3	34.1	7.9	34.0	8.5
36	35.6	5.0	35.6	5.6	35.5	6.3	35.3	6.9	35.2	7.5	35.1	8.1	34.9	8.7
37	36.6	5.1	36.5	5.8	36.4	6.4	36.3	7.1	36.2	7.7	36.1	8.3	35.9	9.0
38	37.6	5.3	37.5	5.9	37.4	6.6	37.3	7.3	37.2	7.9	37.0	8.5	36.9	9.2
39	38.6	5.4	38.5	6.1	38.4	6.8	38.3	7.4	38.1	8.1	38.0	8.8	37.8	9.4
40	39.6	5.6	39.5	6.3	39.4	6.9	39.3	7.6	39.1	8.3	39.0	9.0	38.8	9.7
41	40.6	5.7	40.5	6.4	40.4	7.1	40.2	7.8	40.1	8.5	39.9	9.2	39.8	9.9
42	41.6	5.8	41.5	6.6	41.4	7.3	41.2	8.0	41.1	8.7	40.9	9.4	40.8	10.2
43	42.6	6.0	42.5	6.7	42.3	7.5	42.2	8.2	42.1	8.9	41.9	9.7	41.7	10.4
44	43.6	6.1	43.5	6.9	43.3	7.6	43.2	8.4	43.0	9.1	42.9	9.9	42.7	10.6
45	44.6	6.3	44.4	7.0	44.3	7.8	44.2	8.6	44.0	9.4	43.8	10.1	43.7	10.9
46	45.6	6.4	45.4	7.2	45.3	8.0	45.2	8.8	45.0	9.6	44.8	10.3	44.6	11.1
47	46.5	6.5	46.4	7.4	46.3	8.2	46.1	9.0	46.0	9.8	45.8	10.6	45.6	11.4
48	47.5	6.7	47.4	7.5	47.3	8.3	47.1	9.2	47.0	10.0	46.8	10.8	46.6	11.6
49	48.5	6.8	48.4	7.7	48.3	8.5	48.1	9.3	47.9	10.2	47.7	11.0	47.5	11.9
50	49.5	7.0	49.4	7.8	49.2	8.7	49.1	9.5	48.9	10.4	48.7	11.2	48.5	12.1
100	99.0	13.9	98.8	15.6	98.5	17.4	98.2	19.1	97.8	20.8	97.4	22.5	97.0	24.2
200	198.1	27.8	197.5	31.3	197.0	34.7	196.3	38.2	195.6	41.6	194.9	45.0	194.1	48.4
300	297.1	41.8	296.3	46.9	295.4	52.1	294.5	57.2	293.4	62.4	292.3	67.5	291.1	72.6
400	396.1	55.7	395.1	62.6	393.9	69.5	392.6	76.3	391.3	83.1	389.8	90.0	388.1	96.7
500	495.1	69.6	493.8	78.2	492.4	86.8	490.8	95.4	489.1	104.0	487.2	112.4	485.1	121.0
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.
	(98°, 262°, 278°) 7½ Pt. **82°**		(99°, 261°, 279°) **81°**		(100°, 260°, 280°) **80°**		(101°, 259°, 281°) 7 Pt. **79°**		(102°, 258°, 282°) **78°**		(103°, 257°, 283°) **77°**		(104°, 256°, 284°) 6¾ Pt. **76°**	

The 1-Pt. or 11° Courses are: N. by E., N. by W., S. by E., S. by W.

Dist.	¾ Pt. **8°** (172°, 188°, 352°)		**9°** (171°, 189°, 351°)		**10°** (170°, 190°, 350°)		1 Pt. **11°** (169°, 191°, 349°)		**12°** (168°, 192°, 348°)		**13°** (167°, 193°, 347°)		1¼ Pt. **14°** (166°, 194°, 346°)	
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.
51	50.5	7.1	50.4	8.0	50.2	8.9	50.1	9.7	49.9	10.6	49.7	11.5	49.5	12.3
52	51.5	7.2	51.4	8.1	51.2	9.0	51.0	9.9	50.9	10.8	50.7	11.7	50.5	12.6
53	52.5	7.4	52.3	8.3	52.2	9.2	52.0	10.1	51.8	11.0	51.6	11.9	51.4	12.8
54	53.5	7.5	53.3	8.4	53.2	9.4	53.0	10.3	52.8	11.2	52.6	12.1	52.4	13.1
55	54.5	7.7	54.3	8.6	54.2	9.6	54.0	10.5	53.8	11.4	53.6	12.4	53.4	13.3
56	55.5	7.8	55.3	8.8	55.1	9.7	55.0	10.7	54.8	11.6	54.6	12.6	54.3	13.5
57	56.4	7.9	56.3	8.9	56.1	9.9	56.0	10.9	55.8	11.9	55.5	12.8	55.3	13.8
58	57.4	8.1	57.3	9.1	57.1	10.1	56.9	11.1	56.7	12.1	56.5	13.0	56.3	14.0
59	58.4	8.2	58.3	9.2	58.1	10.2	57.9	11.3	57.7	12.3	57.5	13.3	57.2	14.3
60	59.4	8.4	59.3	9.4	59.1	10.4	58.9	11.4	58.7	12.5	58.5	13.5	58.2	14.5
61	60.4	8.5	60.2	9.5	60.1	10.6	59.9	11.6	59.7	12.7	59.4	13.7	59.2	14.8
62	61.4	8.6	61.2	9.7	61.1	10.8	60.9	11.8	60.6	12.9	60.4	13.9	60.2	15.0
63	62.4	8.8	62.2	9.9	62.0	10.9	61.8	12.0	61.6	13.1	61.4	14.2	61.1	15.2
64	63.4	8.9	63.2	10.0	63.0	11.1	62.8	12.2	62.6	13.3	62.4	14.4	62.1	15.5
65	64.4	9.0	64.2	10.2	64.0	11.3	63.8	12.4	63.6	13.5	63.3	14.6	63.1	15.7
66	65.4	9.2	65.2	10.3	65.0	11.5	64.8	12.6	64.6	13.7	64.3	14.8	64.0	16.0
67	66.3	9.3	66.2	10.5	66.0	11.6	65.8	12.8	65.5	13.9	65.3	15.1	65.0	16.2
68	67.3	9.5	67.2	10.6	67.0	11.8	66.8	13.0	66.5	14.1	66.3	15.3	66.0	16.5
69	68.3	9.6	68.2	10.8	68.0	12.0	67.7	13.2	67.5	14.3	67.2	15.5	67.0	16.7
70	69.3	9.7	69.1	11.0	68.9	12.2	68.7	13.4	68.5	14.6	68.2	15.7	67.9	16.9
71	70.3	9.9	70.1	11.1	69.9	12.3	69.7	13.5	69.4	14.8	69.2	16.0	68.9	17.2
72	71.3	10.0	71.1	11.3	70.9	12.5	70.7	13.7	70.4	15.0	70.2	16.2	69.9	17.4
73	72.3	10.2	72.1	11.4	71.9	12.7	71.7	13.9	71.4	15.2	71.1	16.4	70.8	17.7
74	73.3	10.3	73.1	11.6	72.9	12.8	72.6	14.1	72.4	15.4	72.1	16.6	71.8	17.9
75	74.3	10.4	74.1	11.7	73.9	13.0	73.6	14.3	73.4	15.6	73.1	16.9	72.8	18.1
76	75.3	10.6	75.1	11.9	74.8	13.2	74.6	14.5	74.3	15.8	74.1	17.1	73.7	18.4
77	76.3	10.7	76.1	12.0	75.8	13.4	75.6	14.7	75.3	16.0	75.0	17.3	74.7	18.6
78	77.2	10.9	77.0	12.2	76.8	13.5	76.6	14.9	76.3	16.2	76.0	17.5	75.7	18.9
79	78.2	11.0	78.0	12.4	77.8	13.7	77.5	15.1	77.3	16.4	77.0	17.8	76.7	19.1
80	79.2	11.1	79.0	12.5	78.8	13.9	78.5	15.3	78.3	16.6	77.9	18.0	77.6	19.4
81	80.2	11.3	80.0	12.7	79.8	14.1	79.5	15.5	79.2	16.8	78.9	18.2	78.6	19.6
82	81.2	11.4	81.0	12.8	80.8	14.2	80.5	15.6	80.2	17.0	79.9	18.4	79.6	19.8
83	82.2	11.6	82.0	13.0	81.7	14.4	81.5	15.8	81.2	17.3	80.9	18.7	80.5	20.1
84	83.2	11.7	83.0	13.1	82.7	14.6	82.5	16.0	82.2	17.5	81.8	18.9	81.5	20.3
85	84.2	11.8	84.0	13.3	83.7	14.8	83.4	16.2	83.1	17.7	82.8	19.1	82.5	20.6
86	85.2	12.0	84.9	13.5	84.7	14.9	84.4	16.4	84.1	17.9	83.8	19.3	83.4	20.8
87	86.2	12.1	85.9	13.6	85.7	15.1	85.4	16.6	85.1	18.1	84.8	19.6	84.4	21.0
88	87.1	12.2	86.9	13.8	86.7	15.3	86.4	16.8	86.1	18.3	85.7	19.8	85.4	21.3
89	88.1	12.4	87.9	13.9	87.6	15.5	87.4	17.0	87.1	18.5	86.7	20.0	86.4	21.5
90	89.1	12.5	88.9	14.1	88.6	15.6	88.3	17.2	88.0	18.7	87.7	20.2	87.3	21.8
91	90.1	12.7	89.9	14.2	89.6	15.8	89.3	17.4	89.0	18.9	88.7	20.5	88.3	22.0
92	91.1	12.8	90.9	14.4	90.6	16.0	90.3	17.6	90.0	19.1	89.6	20.7	89.3	22.3
93	92.1	12.9	91.9	14.5	91.6	16.1	91.3	17.7	91.0	19.3	90.6	20.9	90.2	22.5
94	93.1	13.1	92.8	14.7	92.6	16.3	92.3	17.9	91.9	19.5	91.6	21.1	91.2	22.7
95	94.1	13.2	93.8	14.9	93.6	16.5	93.3	18.1	92.9	19.8	92.6	21.4	92.2	23.0
96	95.1	13.4	94.8	15.0	94.5	16.7	94.2	18.3	93.9	20.0	93.5	21.6	93.1	23.2
97	96.1	13.5	95.8	15.2	95.5	16.8	95.2	18.5	94.9	20.2	94.5	21.8	94.1	23.5
98	97.0	13.6	96.8	15.3	96.5	17.0	96.2	18.7	95.9	20.4	95.5	22.0	95.1	23.7
99	98.0	13.8	97.8	15.5	97.5	17.2	97.2	18.9	96.8	20.6	96.5	22.3	96.1	24.0
100	99.0	13.9	98.8	15.6	98.5	17.4	98.2	19.1	97.8	20.8	97.4	22.5	97.0	24.2
600	594.2	83.5	592.6	93.8	590.9	104.2	589.0	114.5	586.9	124.7	584.6	135.0	582.2	145.1
700	693.3	97.4	691.3	109.4	689.5	121.5	687.1	133.6	684.7	145.5	682.1	157.5	679.2	169.3
800	792.3	111.4	790.2	125.1	787.9	139.0	785.2	152.6	782.5	166.3	779.4	180.0	776.2	193.6
900	891.3	125.2	888.8	140.8	886.3	156.3	883.3	171.7	880.2	187.1	876.8	202.4	873.2	217.7
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.
	(98°, 262°, 278°) 7½ Pt. **82°**		(99°, 261°, 279°) **81°**		(100°, 260°, 280°) **80°**		(101°, 259°, 281°) 7 Pt. **79°**		(102°, 258°, 282°) **78°**		(103°, 257°, 283°) **77°**		(104°, 256°, 284°) 6¾ Pt. **76°**	

The 7-Pt. or 79° Courses are: E. by N., W. by N., E. by S., W. by S.

Dist.	15° (165°, 195°, 345°)		16° (164°, 196°, 344°)		1½ Pt. 17° (163°, 197°, 343°)		18° (162°, 198°, 342°)		19° (161°, 199°, 341°)		1¾ Pt. 20° (160°, 200°, 340°)	
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.
1	1.0	0.3	1.0	0.3	1.0	0.3	1.0	0.3	0.9	0.3	0.9	0.3
2	1.9	0.5	1.9	0.6	1.9	0.6	1.9	0.6	1.9	0.7	1.9	0.7
3	2.9	0.8	2.9	0.8	2.9	0.9	2.9	0.9	2.8	1.0	2.8	1.0
4	3.9	1.0	3.8	1.1	3.8	1.2	3.8	1.2	3.8	1.3	3.8	1.4
5	4.8	1.3	4.8	1.4	4.8	1.5	4.8	1.5	4.7	1.6	4.7	1.7
6	5.8	1.6	5.8	1.7	5.7	1.8	5.7	1.9	5.7	2.0	5.6	2.1
7	6.8	1.8	6.7	1.9	6.7	2.0	6.7	2.2	6.6	2.3	6.6	2.4
8	7.7	2.1	7.7	2.2	7.7	2.3	7.6	2.5	7.6	2.6	7.5	2.7
9	8.7	2.3	8.7	2.5	8.6	2.6	8.6	2.8	8.5	2.9	8.5	3.1
10	9.7	2.6	9.6	2.8	9.6	2.9	9.5	3.1	9.5	3.3	9.4	3.4
11	10.6	2.8	10.6	3.0	10.5	3.2	10.5	3.4	10.4	3.6	10.3	3.8
12	11.6	3.1	11.5	3.3	11.5	3.5	11.4	3.7	11.3	3.9	11.3	4.1
13	12.6	3.4	12.5	3.6	12.4	3.8	12.4	4.0	12.3	4.2	12.2	4.4
14	13.5	3.6	13.5	3.9	13.4	4.1	13.3	4.3	13.2	4.6	13.2	4.8
15	14.5	3.9	14.4	4.1	14.3	4.4	14.3	4.6	14.2	4.9	14.1	5.1
16	15.5	4.1	15.4	4.4	15.3	4.7	15.2	4.9	15.1	5.2	15.0	5.5
17	16.4	4.4	16.3	4.7	16.3	5.0	16.2	5.3	16.1	5.5	16.0	5.8
18	17.4	4.7	17.3	5.0	17.2	5.3	17.1	5.6	17.0	5.9	16.9	6.2
19	18.4	4.9	18.3	5.2	18.2	5.6	18.1	5.9	18.0	6.2	17.9	6.5
20	19.3	5.2	19.2	5.5	19.1	5.8	19.0	6.2	18.9	6.5	18.8	6.8
21	20.3	5.4	20.2	5.8	20.1	6.1	20.0	6.5	19.9	6.8	19.7	7.2
22	21.3	5.7	21.1	6.1	21.0	6.4	20.9	6.8	20.8	7.2	20.7	7.5
23	22.2	6.0	22.1	6.3	22.0	6.7	21.9	7.1	21.7	7.5	21.6	7.9
24	23.2	6.2	23.1	6.6	23.0	7.0	22.8	7.4	22.7	7.8	22.6	8.2
25	24.1	6.5	24.0	6.9	23.9	7.3	23.8	7.7	23.6	8.1	23.5	8.6
26	25.1	6.7	25.0	7.2	24.9	7.6	24.7	8.0	24.6	8.5	24.4	8.9
27	26.1	7.0	26.0	7.4	25.8	7.9	25.7	8.3	25.5	8.8	25.4	9.2
28	27.0	7.2	26.9	7.7	26.8	8.2	26.6	8.7	26.5	9.1	26.3	9.6
29	28.0	7.5	27.9	8.0	27.7	8.5	27.6	9.0	27.4	9.4	27.3	9.9
30	29.0	7.8	28.8	8.3	28.7	8.8	28.5	9.3	28.4	9.8	28.2	10.3
31	29.9	8.0	29.8	8.5	29.6	9.1	29.5	9.6	29.3	10.1	29.1	10.6
32	30.9	8.3	30.8	8.8	30.6	9.4	30.4	9.9	30.3	10.4	30.1	10.9
33	31.9	8.5	31.7	9.1	31.6	9.6	31.4	10.2	31.2	10.7	31.0	11.3
34	32.8	8.8	32.7	9.4	32.5	9.9	32.3	10.5	32.1	11.1	31.9	11.6
35	33.8	9.1	33.6	9.6	33.5	10.2	33.3	10.8	33.1	11.4	32.9	12.0
36	34.8	9.3	34.6	9.9	34.4	10.5	34.2	11.1	34.0	11.7	33.8	12.3
37	35.7	9.6	35.6	10.2	35.4	10.8	35.2	11.4	35.0	12.0	34.8	12.7
38	36.7	9.8	36.5	10.5	36.3	11.1	36.1	11.7	35.9	12.4	35.7	13.0
39	37.7	10.1	37.5	10.7	37.3	11.4	37.1	12.1	36.9	12.7	36.6	13.3
40	38.6	10.4	38.5	11.0	38.3	11.7	38.0	12.4	37.8	13.0	37.6	13.7
41	39.6	10.6	39.4	11.3	39.2	12.0	39.0	12.7	38.8	13.3	38.5	14.0
42	40.6	10.9	40.4	11.6	40.2	12.3	39.9	13.0	39.7	13.7	39.5	14.4
43	41.5	11.1	41.3	11.9	41.1	12.6	40.9	13.3	40.7	14.0	40.4	14.7
44	42.5	11.4	42.3	12.1	42.1	12.9	41.8	13.6	41.6	14.3	41.3	15.0
45	43.5	11.6	43.3	12.4	43.0	13.2	42.8	13.9	42.5	14.7	42.3	15.4
46	44.4	11.9	44.2	12.7	44.0	13.4	43.7	14.2	43.5	15.0	43.2	15.7
47	45.4	12.2	45.2	13.0	44.9	13.7	44.7	14.5	44.4	15.3	44.2	16.1
48	46.4	12.4	46.1	13.2	45.9	14.0	45.7	14.8	45.4	15.6	45.1	16.4
49	47.3	12.7	47.1	13.5	46.9	14.3	46.6	15.1	46.3	16.0	46.0	16.8
50	48.3	12.9	48.1	13.8	47.8	14.6	47.6	15.5	47.3	16.3	47.0	17.1
100	96.6	25.9	96.1	27.6	95.6	29.2	95.1	30.9	94.6	32.6	94.0	34.2
200	193.2	51.8	192.3	55.1	191.3	58.5	190.2	61.8	189.1	65.1	187.9	68.4
300	289.8	77.6	288.4	82.7	286.9	87.7	285.3	92.7	283.7	97.7	281.9	102.6
400	386.3	103.5	384.5	110.2	382.5	117.0	380.4	123.6	378.2	130.2	375.9	136.8
500	483.0	129.4	480.6	137.8	478.1	146.2	475.5	154.5	472.8	162.8	469.9	171.0
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.
	(105°, 255°, 285°) 75°		(106°, 254°, 286°) 74°		(107°, 253°, 287°) 6½ Pt. 73°		(108°, 252°, 288°) 72°		(109°, 251°, 289°) 71°		(110°, 250°, 290°) 6¼ Pt. 70°	

Dist.	15° (165°, 195°, 345°)		16° (164°, 196°, 344°)		1½ Pt. 17° (163°, 197°, 343°)		18° (162°, 198°, 342°)		19° (161°, 199°, 341°)		1¾ Pt. 20° (160°, 200°, 340°)	
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.
51	49.3	13.2	49.0	14.1	48.8	14.9	48.5	15.8	48.2	16.6	47.9	17.4
52	50.2	13.5	50.0	14.3	49.7	15.2	49.5	16.1	49.2	16.9	48.9	17.8
53	51.2	13.7	50.9	14.6	50.7	15.5	50.4	16.4	50.1	17.3	49.8	18.1
54	52.2	14.0	51.9	14.9	51.6	15.8	51.4	16.7	51.1	17.6	50.7	18.5
55	53.1	14.2	52.9	15.2	52.6	16.1	52.3	17.0	52.0	17.9	51.7	18.8
56	54.1	14.5	53.8	15.4	53.6	16.4	53.3	17.3	52.9	18.2	52.6	19.2
57	55.1	14.8	54.8	15.7	54.5	16.7	54.2	17.6	53.9	18.6	53.6	19.5
58	56.0	15.0	55.8	16.0	55.5	17.0	55.2	17.9	54.8	18.9	54.5	19.8
59	57.0	15.3	56.7	16.3	56.4	17.2	56.1	18.2	55.8	19.2	55.4	20.2
60	58.0	15.5	57.7	16.5	57.4	17.5	57.1	18.5	56.7	19.5	56.4	20.5
61	58.9	15.8	58.6	16.8	58.3	17.8	58.0	18.9	57.7	19.9	57.3	20.9
62	59.9	16.0	59.6	17.1	59.3	18.1	59.0	19.2	58.6	20.2	58.3	21.2
63	60.9	16.3	60.6	17.4	60.2	18.4	59.9	19.5	59.6	20.5	59.2	21.5
64	61.8	16.6	61.5	17.6	61.2	18.7	60.9	19.8	60.5	20.8	60.1	21.9
65	62.8	16.8	62.5	17.9	62.2	19.0	61.8	20.1	61.5	21.2	61.1	22.2
66	63.8	17.1	63.4	18.2	63.1	19.3	62.8	20.4	62.4	21.5	62.0	22.6
67	64.7	17.3	64.4	18.5	64.1	19.6	63.7	20.7	63.3	21.8	63.0	22.9
68	65.7	17.6	65.4	18.7	65.0	19.9	64.7	21.0	64.3	22.1	63.9	23.3
69	66.6	17.9	66.3	19.0	66.0	20.2	65.6	21.3	65.2	22.5	64.8	23.6
70	67.6	18.1	67.3	19.3	66.9	20.5	66.6	21.6	66.2	22.8	65.8	23.9
71	68.6	18.4	68.2	19.6	67.9	20.8	67.5	21.9	67.1	23.1	66.7	24.3
72	69.5	18.6	69.2	19.8	68.9	21.1	68.5	22.2	68.1	23.4	67.7	24.6
73	70.5	18.9	70.2	20.1	69.8	21.3	69.4	22.6	69.0	23.8	68.6	25.0
74	71.5	19.2	71.1	20.4	70.8	21.6	70.4	22.9	70.0	24.1	69.5	25.3
75	72.4	19.4	72.1	20.7	71.7	21.9	71.3	23.2	70.9	24.4	70.5	25.7
76	73.4	19.7	73.1	20.9	72.7	22.2	72.3	23.5	71.9	24.7	71.4	26.0
77	74.4	19.9	74.0	21.2	73.6	22.5	73.2	23.8	72.8	25.1	72.4	26.3
78	75.3	20.2	75.0	21.5	74.6	22.8	74.2	24.1	73.8	25.4	73.3	26.7
79	76.3	20.4	75.9	21.8	75.5	23.1	75.1	24.4	74.7	25.7	74.2	27.0
80	77.3	20.7	76.9	22.1	76.5	23.4	76.1	24.7	75.6	26.0	75.2	27.4
81	78.2	21.0	77.9	22.3	77.5	23.7	77.0	25.0	76.6	26.4	76.1	27.7
82	79.2	21.2	78.8	22.6	78.4	24.0	78.0	25.3	77.5	26.7	77.1	28.0
83	80.2	21.5	79.8	22.9	79.4	24.3	78.9	25.6	78.5	27.0	78.0	28.4
84	81.1	21.7	80.7	23.2	80.3	24.6	79.9	26.0	79.4	27.3	78.9	28.7
85	82.1	22.0	81.7	23.4	81.3	24.9	80.8	26.3	80.4	27.7	79.9	29.1
86	83.1	22.3	82.7	23.7	82.2	25.1	81.8	26.6	81.3	28.0	80.8	29.4
87	84.0	22.5	83.6	24.0	83.2	25.4	82.7	26.9	82.3	28.3	81.8	29.8
88	85.0	22.8	84.6	24.3	84.2	25.7	83.7	27.2	83.2	28.7	82.7	30.1
89	86.0	23.0	85.6	24.5	85.1	26.0	84.6	27.5	84.2	29.0	83.6	30.4
90	86.9	23.3	86.5	24.8	86.1	26.3	85.6	27.8	85.1	29.3	84.6	30.8
91	87.9	23.6	87.5	25.1	87.0	26.6	86.5	28.1	86.0	29.6	85.5	31.1
92	88.9	23.8	88.4	25.4	88.0	26.9	87.5	28.4	87.0	30.0	86.5	31.5
93	89.8	24.1	89.4	25.6	88.9	27.2	88.4	28.7	87.9	30.3	87.4	31.8
94	90.8	24.3	90.4	25.9	89.9	27.5	89.4	29.0	88.9	30.6	88.3	32.1
95	91.8	24.6	91.3	26.2	90.8	27.8	90.4	29.4	89.8	30.9	89.3	32.5
96	92.7	24.8	92.3	26.5	91.8	28.1	91.3	29.7	90.8	31.3	90.2	32.8
97	93.7	25.1	93.2	26.7	92.8	28.4	92.3	30.0	91.7	31.6	91.2	33.2
98	94.7	25.4	94.2	27.0	93.7	28.7	93.2	30.3	92.7	31.9	92.1	33.5
99	95.6	25.6	95.2	27.3	94.7	28.9	94.2	30.6	93.6	32.2	93.0	33.9
100	96.6	25.9	96.1	27.6	95.6	29.2	95.1	30.9	94.6	32.6	94.0	34.2
600	579.5	155.3	576.8	165.4	573.8	175.4	570.6	185.4	567.3	195.3	563.8	205.2
700	676.1	181.1	672.8	193.0	669.4	204.6	665.8	216.3	661.9	227.9	657.9	239.4
800	772.7	207.0	769.0	220.5	765.0	233.9	760.8	247.3	756.5	260.4	751.8	273.6
900	869.2	232.9	865.0	248.0	860.6	263.1	855.9	278.1	850.9	292.9	845.7	307.8
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.
	(105°, 255°, 285°) 75°		(106°, 254°, 286°) 74°		(107°, 253°, 287°) 6½ Pt. 73°		(108°, 252°, 288°) 72°		(109°, 251°, 289°) 71°		(110°, 250°, 290°) 70°	

Dist.	21° (159°, 201°, 339°)		22° (158°, 202°, 338°)		2 Pt. 23° (157°, 203°, 337°)		24° (156°, 204°, 336°)		2¼ Pt. 25° (155°, 205°, 335°)		26° (154°, 206°, 334°)	
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.
1	0.9	0.4	0.9	0.4	0.9	0.4	0.9	0.4	0.9	0.4	0.9	0.4
2	1.9	0.7	1.9	0.7	1.8	0.8	1.8	0.8	1.8	0.8	1.8	0.9
3	2.8	1.1	2.8	1.1	2.8	1.2	2.7	1.2	2.7	1.3	2.7	1.3
4	3.7	1.4	3.7	1.5	3.7	1.6	3.7	1.6	3.6	1.7	3.6	1.8
5	4.7	1.8	4.6	1.9	4.6	2.0	4.6	2.0	4.5	2.1	4.5	2.2
6	5.6	2.2	5.6	2.2	5.5	2.3	5.5	2.4	5.4	2.5	5.4	2.6
7	6.5	2.5	6.5	2.6	6.4	2.7	6.4	2.8	6.3	3.0	6.3	3.1
8	7.5	2.9	7.4	3.0	7.4	3.1	7.3	3.3	7.3	3.4	7.2	3.5
9	8.4	3.2	8.3	3.4	8.3	3.5	8.2	3.7	8.2	3.8	8.1	3.9
10	9.3	3.6	9.3	3.7	9.2	3.9	9.1	4.1	9.1	4.2	9.0	4.4
11	10.3	3.9	10.2	4.1	10.1	4.3	10.0	4.5	10.0	4.6	9.9	4.8
12	11.2	4.3	11.1	4.5	11.0	4.7	11.0	4.9	10.9	5.1	10.8	5.3
13	12.1	4.7	12.1	4.9	12.0	5.1	11.9	5.3	11.8	5.5	11.7	5.7
14	13.1	5.0	13.0	5.2	12.9	5.5	12.8	5.7	12.7	5.9	12.6	6.1
15	14.0	5.4	13.9	5.6	13.8	5.9	13.7	6.1	13.6	6.3	13.5	6.6
16	14.9	5.7	14.8	6.0	14.7	6.3	14.6	6.5	14.5	6.8	14.4	7.0
17	15.9	6.1	15.8	6.4	15.6	6.6	15.5	6.9	15.4	7.2	15.3	7.5
18	16.8	6.5	16.7	6.7	16.6	7.0	16.4	7.3	16.3	7.6	16.2	7.9
19	17.7	6.8	17.6	7.1	17.5	7.4	17.4	7.7	17.2	8.0	17.1	8.3
20	18.7	7.2	18.5	7.5	18.4	7.8	18.3	8.1	18.1	8.5	18.0	8.8
21	19.6	7.5	19.5	7.9	19.3	8.2	19.2	8.5	19.0	8.9	18.9	9.2
22	20.5	7.9	20.4	8.2	20.3	8.6	20.1	8.9	19.9	9.3	19.8	9.6
23	21.5	8.2	21.3	8.6	21.2	9.0	21.0	9.4	20.8	9.7	20.7	10.1
24	22.4	8.6	22.3	9.0	22.1	9.4	21.9	9.8	21.8	10.1	21.6	10.5
25	23.3	9.0	23.2	9.4	23.0	9.8	22.8	10.2	22.7	10.6	22.5	11.0
26	24.3	9.3	24.1	9.7	23.9	10.2	23.8	10.6	23.6	11.0	23.4	11.4
27	25.2	9.7	25.0	10.1	24.9	10.5	24.7	11.0	24.5	11.4	24.3	11.8
28	26.1	10.0	26.0	10.5	25.8	10.9	25.6	11.4	25.4	11.8	25.2	12.3
29	27.1	10.4	26.9	10.9	26.7	11.3	26.5	11.8	26.3	12.3	26.1	12.7
30	28.0	10.8	27.8	11.2	27.6	11.7	27.4	12.2	27.2	12.7	27.0	13.2
31	28.9	11.1	28.7	11.6	28.5	12.1	28.3	12.6	28.1	13.1	27.9	13.6
32	29.9	11.5	29.7	12.0	29.5	12.5	29.2	13.0	29.0	13.5	28.8	14.0
33	30.8	11.8	30.6	12.4	30.4	12.9	30.1	13.4	29.9	13.9	29.7	14.5
34	31.7	12.2	31.5	12.7	31.3	13.3	31.1	13.8	30.8	14.4	30.6	14.9
35	32.7	12.5	32.5	13.1	32.2	13.7	32.0	14.2	31.7	14.8	31.5	15.3
36	33.6	12.9	33.4	13.5	33.1	14.1	32.9	14.6	32.6	15.2	32.4	15.8
37	34.5	13.3	34.3	13.9	34.1	14.5	33.8	15.0	33.5	15.6	33.3	16.2
38	35.5	13.6	35.2	14.2	35.0	14.8	34.7	15.5	34.4	16.1	34.2	16.7
39	36.4	14.0	36.2	14.6	35.9	15.2	35.6	15.9	35.3	16.5	35.1	17.1
40	37.3	14.3	37.1	15.0	36.8	15.6	36.5	16.3	36.3	16.9	36.0	17.5
41	38.3	14.7	38.0	15.4	37.7	16.0	37.5	16.7	37.2	17.3	36.9	18.0
42	39.2	15.1	38.9	15.7	38.7	16.4	38.4	17.1	38.1	17.7	37.7	18.4
43	40.1	15.4	39.9	16.1	39.6	16.8	39.3	17.5	39.0	18.2	38.6	18.8
44	41.1	15.8	40.8	16.5	40.5	17.2	40.2	17.9	39.9	18.6	39.5	19.3
45	42.0	16.1	41.7	16.9	41.4	17.6	41.1	18.3	40.8	19.0	40.4	19.7
46	42.9	16.5	42.7	17.2	42.3	18.0	42.0	18.7	41.7	19.4	41.3	20.2
47	43.9	16.8	43.6	17.6	43.3	18.4	42.9	19.1	42.6	19.9	42.2	20.6
48	44.8	17.2	44.5	18.0	44.2	18.8	43.9	19.5	43.5	20.3	43.1	21.0
49	45.7	17.6	45.4	18.4	45.1	19.1	44.8	19.9	44.4	20.7	44.0	21.5
50	46.7	17.9	46.4	18.7	46.0	19.5	45.7	20.3	45.3	21.1	44.9	21.9
100	93.4	35.8	92.7	37.5	92.1	39.1	91.4	40.7	90.6	42.3	89.9	43.8
200	186.7	71.7	185.4	74.9	184.1	78.1	182.7	81.3	181.3	84.5	179.8	87.7
300	280.1	107.5	278.2	112.4	276.2	117.2	274.1	122.0	271.9	126.8	269.6	131.5
400	373.4	143.4	370.9	149.8	368.2	156.3	365.4	162.7	362.5	169.0	359.5	175.4
500	466.8	179.2	463.6	187.3	460.2	195.4	456.8	203.4	453.1	211.3	449.4	219.2
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.
	(111°, 249°, 291°) 69°		(112°, 248,° 292°) 6 Pt. 68°		(113°. 247°, 293°) 67°		(114°, 246°, 294°) 66°		(115°, 245°, 295°) 5¾ Pt. 65°		(116°, 244°, 296°) 64°	

The 2-Pt. or 23° Courses are: N.N.E., N.N.W., S.S.E., S.S.W.

Dist.	21° (159°, 201°, 339°)		22° (158°, 202°, 338°)		2 Pt. 23° (157°, 203°, 337°)		24° (156°, 204°, 336°)		2¼ Pt. 25° (155°, 205°, 335°)		26° (154°, 206°, 334°)	
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.
51	47.6	18.3	47.3	19.1	46.9	19.9	46.6	20.7	46.2	21.6	45.8	22.4
52	48.5	18.6	48.2	19.5	47.9	20.3	47.5	21.2	47.1	22.0	46.7	22.8
53	49.5	19.0	49.1	19.9	48.8	20.7	48.4	21.6	48.0	22.4	47.6	23.2
54	50.4	19.4	50.1	20.2	49.7	21.1	49.3	22.0	48.9	22.8	48.5	23.7
55	51.3	19.7	51.0	20.6	50.6	21.5	50.2	22.4	49.8	23.2	49.4	24.1
56	52.3	20.1	51.9	21.0	51.5	21.9	51.2	22.8	50.8	23.7	50.3	24.5
57	53.2	20.4	52.8	21.4	52.5	22.3	52.1	23.2	51.7	24.1	51.2	25.0
58	54.1	20.8	53.8	21.7	53.4	22.7	53.0	23.6	52.6	24.5	52.1	25.4
59	55.1	21.1	54.7	22.1	54.3	23.1	53.9	24.0	53.5	24.9	53.0	25.9
60	56.0	21.5	55.6	22.5	55.2	23.4	54.8	24.4	54.4	25.4	53.9	26.3
61	56.9	21.9	56.6	22.9	56.2	23.8	55.7	24.8	55.3	25.8	54.8	26.7
62	57.9	22.2	57.5	23.2	57.1	24.2	56.6	25.2	56.2	26.2	55.7	27.2
63	58.8	22.6	58.4	23.6	58.0	24.6	57.6	25.6	57.1	26.6	56.6	27.6
64	59.7	22.9	59.3	24.0	58.9	25.0	58.5	26.0	58.0	27.0	57.5	28.1
65	60.7	23.3	60.3	24.3	59.8	25.4	59.4	26.4	58.9	27.5	58.4	28.5
66	61.6	23.7	61.2	24.7	60.8	25.8	60.3	26.8	59.8	27.9	59.3	28.9
67	62.5	24.0	62.1	25.1	61.7	26.2	61.2	27.3	60.7	28.3	60.2	29.4
68	63.5	24.4	63.0	25.5	62.6	26.6	62.1	27.7	61.6	28.7	61.1	29.8
69	64.4	24.7	64.0	25.8	63.5	27.0	63.0	28.1	62.5	29.2	62.0	30.2
70	65.4	25.1	64.9	26.2	64.4	27.4	63.9	28.5	63.4	29.6	62.9	30.7
71	66.3	25.4	65.8	26.6	65.4	27.7	64.9	28.9	64.3	30.0	63.8	31.1
72	67.2	25.8	66.8	27.0	66.3	28.1	65.8	29.3	65.3	30.4	64.7	31.6
73	68.2	26.2	67.7	27.3	67.2	28.5	66.7	29.7	66.2	30.9	65.6	32.0
74	69.1	26.5	68.6	27.7	68.1	28.9	67.6	30.1	67.1	31.3	66.5	32.4
75	70.0	26.9	69.5	28.1	69.0	29.3	68.5	30.5	68.0	31.7	67.4	32.9
76	71.0	27.2	70.5	28.5	70.0	29.7	69.4	30.9	68.9	32.1	68.3	33.3
77	71.9	27.6	71.4	28.8	70.9	30.1	70.3	31.3	69.8	32.5	69.2	33.8
78	72.8	28.0	72.3	29.2	71.8	30.5	71.3	31.7	70.7	33.0	70.1	34.2
79	73.0	28.3	73.2	29.6	72.7	30.9	72.2	32.1	71.6	33.4	71.0	34.6
80	74.7	28.7	74.2	30.0	73.6	31.3	73.1	32.5	72.5	33.8	71.9	35.1
81	75.6	29.0	75.1	30.3	74.6	31.6	74.0	32.9	73.4	34.2	72.8	35.5
82	76.6	29.4	76.0	30.7	75.5	32.0	74.9	33.4	74.3	34.7	73.7	35.9
83	77.5	29.7	77.0	31.1	76.4	32.4	75.8	33.8	75.2	35.1	74.6	36.4
84	78.4	30.1	77.9	31.5	77.3	32.8	76.7	34.2	76.1	35.5	75.5	36.8
85	79.4	30.5	78.8	31.8	78.2	33.2	77.7	34.6	77.0	35.9	76.4	37.3
86	80.3	30.8	79.7	32.2	79.2	33.6	78.6	35.0	77.9	36.3	77.3	37.7
87	81.2	31.2	80.7	32.6	80.1	34.0	79.5	35.4	78.8	36.8	78.2	38.1
88	82.2	31.5	81.6	33.0	81.0	34.4	80.4	35.8	79.8	37.2	79.1	38.6
89	83.1	31.9	82.5	33.3	81.9	34.8	81.3	36.2	80.7	37.6	80.0	39.0
90	84.0	32.3	83.4	33.7	82.8	35.2	82.2	36.6	81.6	38.0	80.9	39.5
91	85.0	32.6	84.4	34.1	83.8	35.6	83.1	37.0	82.5	38.5	81.8	39.9
92	85.9	33.0	85.3	34.5	84.7	35.9	84.0	37.4	83.4	38.9	82.7	40.3
93	86.8	33.3	86.2	34.8	85.6	36.3	85.0	37.8	84.3	39.3	83.6	40.8
94	87.8	33.7	87.2	35.2	86.5	36.7	85.9	38.2	85.2	39.7	84.5	41.2
95	88.7	34.0	88.1	35.6	87.4	37.1	86.8	38.6	86.1	40.1	85.4	41.6
96	89.6	34.4	89.0	36.0	88.4	37.5	87.7	39.0	87.0	40.6	86.3	42.1
97	90.6	34.8	89.9	36.3	89.3	37.9	88.6	39.5	87.9	41.0	87.2	42.5
98	91.5	35.1	90.9	36.7	90.2	38.3	89.5	39.9	88.8	41.4	88.1	43.0
99	92.4	35.5	91.8	37.1	91.1	38.7	90.4	40.3	89.7	41.8	89.0	43.4
100	93.4	35.8	92.7	37.5	92.1	39.1	91.4	40.7	90.6	42.3	89.9	43.8
600	560.1	215.0	556.3	224.8	552.3	234.4	548.1	244.0	543.8	253.6	539.3	263.0
700	653.6	250.8	649.1	262.2	644.3	273.5	639.5	284.7	634.5	295.8	629.2	306.8
800	746.9	286.7	741.8	299.7	736.4	312.6	730.8	325.4	725.1	338.1	719.1	350.6
900	840.3	322.5	834.5	337.1	828.3	351.7	822.1	366.0	815.6	380.3	808.9	394.5
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.
	(111°, 249°, 291°) 69°		(112°, 248°, 292°) 6 Pt. 68°		(113°, 247°, 293°) 67°		(114°, 246°, 294°) 66°		(115°, 245°, 295°) 5¾ Pt. 65°		(116°, 244°, 296°) 64°	

The 6-Pt. or 68° Courses are: E.N.E., W.N.W., E.S.E., W.S.W.

Dist.	27° (153°, 207°, 333°)		2½ Pt. 28° (152°, 208°, 332°)		29° (151°, 209°, 331°)		30° (150°, 210°, 330°)		2¾ Pt. 31° (149°, 211°, 329°)		32° (148°, 212°, 328°)	
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.
1	0.9	0.5	0.9	0.5	0.9	0.5	0.9	0.5	0.9	0.5	0.8	0.5
2	1.8	0.9	1.8	0.9	1.7	1.0	1.7	1.0	1.7	1.0	1.7	1.1
3	2.7	1.4	2.6	1.4	2.6	1.5	2.6	1.5	2.6	1.5	2.5	1.6
4	3.6	1.8	3.5	1.9	3.5	1.9	3.5	2.0	3.4	2.1	3.4	2.1
5	4.5	2.3	4.4	2.3	4.4	2.4	4.3	2.5	4.3	2.6	4.2	2.6
6	5.3	2.7	5.3	2.8	5.2	2.9	5.2	3.0	5.1	3.1	5.1	3.2
7	6.2	3.2	6.2	3.3	6.1	3.4	6.1	3.5	6.0	3.6	5.9	3.7
8	7.1	3.6	7.1	3.8	7.0	3.9	6.9	4.0	6.9	4.1	6.8	4.2
9	8.0	4.1	7.9	4.2	7.9	4.4	7.8	4.5	7.7	4.6	7.6	4.8
10	8.9	4.5	8.8	4.7	8.7	4.8	8.7	5.0	8.6	5.2	8.5	5.3
11	9.8	5.0	9.7	5.2	9.6	5.3	9.5	5.5	9.4	5.7	9.3	5.8
12	10.7	5.4	10.6	5.6	10.5	5.8	10.4	6.0	10.3	6.2	10.2	6.4
13	11.6	5.9	11.5	6.1	11.4	6.3	11.3	6.5	11.1	6.7	11.0	6.9
14	12.5	6.4	12.4	6.6	12.2	6.8	12.1	7.0	12.0	7.2	11.9	7.4
15	13.4	6.8	13.2	7.0	13.1	7.3	13.0	7.5	12.9	7.7	12.7	7.9
16	14.3	7.3	14.1	7.5	14.0	7.8	13.9	8.0	13.7	8.2	13.6	8.5
17	15.1	7.7	15.0	8.0	14.9	8.2	14.7	8.5	14.6	8.8	14.4	9.0
18	16.0	8.2	15.9	8.5	15.7	8.7	15.6	9.0	15.4	9.3	15.3	9.5
19	16.9	8.6	16.8	8.9	16.6	9.2	16.5	9.5	16.3	9.8	16.1	10.1
20	17.8	9.1	17.7	9.4	17.5	9.7	17.3	10.0	17.1	10.3	17.0	10.6
21	18.7	9.5	18.5	9.9	18.4	10.2	18.2	10.5	18.0	10.8	17.8	11.1
22	19.6	10.0	19.4	10.3	19.2	10.7	19.1	11.0	18.9	11.3	18.7	11.7
23	20.5	10.4	20.3	10.8	20.1	11.2	19.9	11.5	19.7	11.8	19.5	12.2
24	21.4	10.9	21.2	11.3	21.0	11.6	20.8	12.0	20.6	12.4	20.4	12.7
25	22.3	11.3	22.1	11.7	21.9	12.1	21.7	12.5	21.4	12.9	21.2	13.2
26	23.2	11.8	23.0	12.2	22.7	12.6	22.5	13.0	22.3	13.4	22.0	13.8
27	24.1	12.3	23.8	12.7	23.6	13.1	23.4	13.5	23.1	13.9	22.9	14.3
28	24.9	12.7	24.7	13.1	24.5	13.6	24.2	14.0	24.0	14.4	23.7	14.8
29	25.8	13.2	25.6	13.6	25.4	14.1	25.1	14.5	24.9	14.9	24.6	15.4
30	26.7	13.6	26.5	14.1	26.2	14.5	26.0	15.0	25.7	15.5	25.4	15.9
31	27.6	14.1	27.4	14.6	27.1	15.0	26.8	15.5	26.6	16.0	26.3	16.4
32	28.5	14.5	28.3	15.0	28.0	15.5	27.7	16.0	27.4	16.5	27.1	17.0
33	29.4	15.0	29.1	15.5	28.9	16.0	28.6	16.5	28.3	17.0	28.0	17.5
34	30.3	15.4	30.0	16.0	29.7	16.5	29.4	17.0	29.1	17.5	28.8	18.0
35	31.2	15.9	30.9	16.4	30.6	17.0	30.3	17.5	30.0	18.0	29.7	18.5
36	32.1	16.3	31.8	16.9	31.5	17.5	31.2	18.0	30.9	18.5	30.5	19.1
37	33.0	16.8	32.7	17.4	32.4	17.9	32.0	18.5	31.7	19.1	31.4	19.6
38	33.9	17.3	33.6	17.8	33.2	18.4	32.9	19.0	32.6	19.6	32.2	20.1
39	34.7	17.7	34.4	18.3	34.1	18.9	33.8	19.5	33.4	20.1	33.1	20.7
40	35.6	18.2	35.3	18.8	35.0	19.4	34.6	20.0	34.3	20.6	33.9	21.2
41	36.5	18.6	36.2	19.2	35.9	19.9	35.5	20.5	35.1	21.1	34.8	21.7
42	37.4	19.1	37.1	19.7	36.7	20.4	36.4	21.0	36.0	21.6	35.6	22.3
43	38.3	19.5	38.0	20.2	37.6	20.8	37.2	21.5	36.9	22.1	36.5	22.8
44	39.2	20.0	38.8	20.7	38.5	21.3	38.1	22.0	37.7	22.7	37.3	23.3
45	40.1	20.4	39.7	21.1	39.4	21.8	39.0	22.5	38.6	23.2	38.2	23.8
46	41.0	20.9	40.6	21.6	40.2	22.3	39.8	23.0	39.4	23.7	39.0	24.4
47	41.9	21.3	41.5	22.1	41.1	22.8	40.7	23.5	40.3	24.2	39.9	24.9
48	42.8	21.8	42.4	22.5	42.0	23.3	41.6	24.0	41.1	24.7	40.7	25.4
49	43.7	22.2	43.3	23.0	42.9	23.8	42.4	24.5	42.0	25.2	41.6	26.0
50	44.6	22.7	44.1	23.5	43.7	24.2	43.3	25.0	42.9	25.8	42.4	26.5
100	89.1	45.4	88.3	46.9	87.5	48.5	86.6	50.0	85.7	51.5	84.8	53.0
200	178.2	90.8	176.6	93.9	174.9	97.0	173.2	100.0	171.4	103.0	169.6	106.0
300	267.3	136.2	264.9	140.8	262.4	145.4	259.8	150.0	257.1	154.5	254.4	159.0
400	356.4	181.6	353.1	187.8	349.8	193.9	346.4	200.0	342.9	206.0	339.2	211.9
500	445.5	227.0	441.5	234.7	437.3	242.4	433.0	250.0	428.6	257.5	424.0	265.0
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.
	(117°, 243°, 297°) 63°		(118°, 242°, 298°) 5½ Pt. 62°		(119°, 241°, 299°) 61°		(120°, 240°, 300°) 60°		(121°, 239°, 301°) 5¼ Pt. 59°		(122°, 238°, 302°) 58°	

Dist.	27° (153°, 207°, 333°)		2½ Pt. 28° (152°, 208°, 332°)		29° (151°, 209°, 331°)		30° (150°, 210°, 330°)		2¾ Pt. 31° (149°, 211°, 329°)		32° (148°, 212°, 328°)	
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.
51	45.4	23.2	45.0	23.9	44.6	24.7	44.2	25.5	43.7	26.3	43.3	27.0
52	46.3	23.6	45.9	24.4	45.5	25.2	45.0	26.0	44.6	26.8	44.1	27.6
53	47.2	24.1	46.8	24.9	46.4	25.7	45.9	26.5	45.4	27.3	44.9	28.1
54	48.1	24.5	47.7	25.4	47.2	26.2	46.8	27.0	46.3	27.8	45.8	28.6
55	49.0	25.0	48.6	25.8	48.1	26.7	47.6	27.5	47.1	28.3	46.6	29.1
56	49.9	25.4	49.4	26.3	49.0	27.1	48.5	28.0	48.0	28.8	47.5	29.7
57	50.8	25.9	50.3	26.8	49.9	27.6	49.4	28.5	48.9	29.4	48.3	30.2
58	51.7	26.3	51.2	27.2	50.7	28.1	50.2	29.0	49.7	29.9	49.2	30.7
59	52.6	26.8	52.1	27.7	51.6	28.6	51.1	29.5	50.6	30.4	50.0	31.3
60	53.5	27.2	53.0	28.2	52.5	29.1	52.0	30.0	51.4	30.9	50.9	31.8
61	54.4	27.7	53.9	28.6	53.4	29.6	52.8	30.5	52.3	31.4	51.7	32.3
62	55.2	28.1	54.7	29.1	54.2	30.1	53.7	31.0	53.1	31.9	52.6	32.9
63	56.1	28.6	55.6	29.6	55.1	30.5	54.6	31.5	54.0	32.4	53.4	33.4
64	57.0	29.1	56.5	30.0	56.0	31.0	55.4	32.0	54.9	33.0	54.3	33.9
65	57.9	29.5	57.4	30.5	56.9	31.5	56.3	32.5	55.7	33.5	55.1	34.4
66	58.8	30.0	58.3	31.0	57.7	32.0	57.2	33.0	56.6	34.0	56.0	35.0
67	59.7	30.4	59.2	31.5	58.6	32.5	58.0	33.5	57.4	34.5	56.8	35.5
68	60.6	30.9	60.0	31.9	59.5	33.0	58.9	34.0	58.3	35.0	57.7	36.0
69	61.5	31.3	60.9	32.4	60.3	33.5	59.8	34.5	59.1	35.5	58.5	36.6
70	62.4	31.8	61.8	32.9	61.2	33.9	60.6	35.0	60.0	36.1	59.4	37.1
71	63.3	32.2	62.7	33.3	62.1	34.4	61.5	35.5	60.9	36.6	60.2	37.6
72	64.2	32.7	63.6	33.8	63.0	34.9	62.4	36.0	61.7	37.1	61.1	38.2
73	65.0	33.1	64.5	34.3	63.8	35.4	63.2	36.5	62.6	37.6	61.9	38.7
74	65.9	33.6	65.3	34.7	64.7	35.9	64.1	37.0	63.4	38.1	62.8	39.2
75	66.8	34.0	66.2	35.2	65.6	36.4	65.0	37.5	64.3	38.6	63.6	39.7
76	67.7	34.5	67.1	35.7	66.5	36.8	65.8	38.0	65.1	39.1	64.5	40.3
77	68.6	35.0	68.0	36.1	67.3	37.3	66.7	38.5	66.0	39.7	65.3	40.8
78	69.5	35.4	68.9	36.6	68.2	37.8	67.5	39.0	66.9	40.2	66.1	41.3
79	70.4	35.9	69.8	37.1	69.1	38.3	68.4	39.5	67.7	40.7	67.0	41.9
80	71.3	36.3	70.6	37.6	70.0	38.8	69.3	40.0	68.6	41.2	67.8	42.4
81	72.2	36.8	71.5	38.0	70.8	39.3	70.1	40.5	69.4	41.7	68.7	42.9
82	73.1	37.2	72.4	38.5	71.7	39.8	71.0	41.0	70.3	42.2	69.5	43.5
83	74.0	37.7	73.3	39.0	72.6	40.2	71.9	41.5	71.1	42.7	70.4	44.0
84	74.8	38.1	74.2	39.4	73.5	40.7	72.7	42.0	72.0	43.3	71.2	44.5
85	75.7	38.6	75.1	39.9	74.3	41.2	73.6	42.5	72.9	43.8	72.1	45.0
86	76.6	39.0	75.9	40.4	75.2	41.7	74.5	43.0	73.7	44.3	72.9	45.6
87	77.5	39.5	76.8	40.8	76.1	42.2	75.3	43.5	74.6	44.8	73.8	46.1
88	78.4	40.0	77.7	41.3	77.0	42.7	76.2	44.0	75.4	45.3	74.6	46.6
89	79.3	40.4	78.6	41.8	77.8	43.1	77.1	44.5	76.3	45.8	75.5	47.2
90	80.2	40.9	79.5	42.3	78.7	43.6	77.9	45.0	77.1	46.4	76.3	47.7
91	81.1	41.3	80.3	42.7	79.6	44.1	78.8	45.5	78.0	46.9	77.2	48.2
92	82.0	41.8	81.2	43.2	80.5	44.6	79.7	46.0	78.9	47.4	78.0	48.8
93	82.9	42.2	82.1	43.7	81.3	45.1	80.5	46.5	79.7	47.9	78.9	49.3
94	83.8	42.7	83.0	44.1	82.2	45.6	81.4	47.0	80.6	48.4	79.7	49.8
95	84.6	43.1	83.9	44.6	83.1	46.1	82.3	47.5	81.4	48.9	80.6	50.3
96	85.5	43.6	84.8	45.1	84.0	46.5	83.1	48.0	82.3	49.4	81.4	50.9
97	86.4	44.0	85.6	45.5	84.8	47.0	84.0	48.5	83.1	50.0	82.3	51.4
98	87.3	44.5	86.5	46.0	85.7	47.5	84.9	49.0	84.0	50.5	83.1	51.9
99	88.2	44.9	87.4	46.5	86.6	48.0	85.7	49.5	84.9	51.0	84.0	52.5
100	89.1	45.4	88.3	46.9	87.5	48.5	86.6	50.0	85.7	51.5	84.8	53.0
600	534.6	272.4	529.8	281.7	524.8	290.9	519.6	300.0	514.3	309.0	508.8	318.0
700	623.7	317.8	618.0	328.6	612.2	339.4	606.1	350.0	600.1	360.4	593.6	371.0
800	712.9	363.2	706.3	375.6	699.7	387.9	692.8	400.0	685.8	412.0	678.4	423.9
900	801.9	408.5	794.5	422.5	787.0	436.3	779.3	450.0	771.4	463.4	763.2	476.8
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.
	(117°, 243°, 297°) 63°		(118°, 242°, 298°) 5½ Pt. 62°		(119°, 241°, 299°) 61°		(120°, 240° 300°) 60°		(121°, 239°, 301°) 5¼ Pt. 59°		(122°, 238°, 302°) 58°	

Dist.	33° (147°, 213°, 327°)		3 Pt. 34° (146°, 214°, 326°)		35° (145°, 215°, 325°)		36° (144°, 216°, 324°)		$3\frac{1}{4}$ Pt. 37° (143°, 217°, 323°)		38° (142°, 218°, 322°)	
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.
1	0.8	0.5	0.8	0.6	0.8	0.6	0.8	0.6	0.8	0.6	0.8	0.6
2	1.7	1.1	1.7	1.1	1.6	1.1	1.6	1.2	1.6	1.2	1.6	1.2
3	2.5	1.6	2.5	1.7	2.5	1.7	2.4	1.8	2.4	1.8	2.4	1.8
4	3.4	2.2	3.3	2.2	3.3	2.3	3.2	2.4	3.2	2.4	3.2	2.5
5	4.2	2.7	4.1	2.8	4.1	2.9	4.0	2.9	4.0	3.0	3.9	3.1
6	5.0	3.3	5.0	3.4	4.9	3.4	4.9	3.5	4.8	3.6	4.7	3.7
7	5.9	3.8	5.8	3.9	5.7	4.0	5.7	4.1	5.6	4.2	5.5	4.3
8	6.7	4.4	6.6	4.5	6.6	4.6	6.5	4.7	6.4	4.8	6.3	4.9
9	7.5	4.9	7.5	5.0	7.4	5.2	7.3	5.3	7.2	5.4	7.1	5.5
10	8.4	5.4	8.3	5.6	8.2	5.7	8.1	5.9	8.0	6.0	7.9	6.2
11	9.2	6.0	9.1	6.2	9.0	6.3	8.9	6.5	8.8	6.6	8.7	6.8
12	10.1	6.5	9.9	6.7	9.8	6.9	9.7	7.1	9.6	7.2	9.5	7.4
13	10.9	7.1	10.8	7.3	10.6	7.5	10.5	7.6	10.4	7.8	10.2	8.0
14	11.7	7.6	11.6	7.8	11.5	8.0	11.3	8.2	11.2	8.4	11.0	8.6
15	12.6	8.2	12.4	8.4	12.3	8.6	12.1	8.8	12.0	9.0	11.8	9.2
16	13.4	8.7	13.3	8.9	13.1	9.2	12.9	9.4	12.8	9.6	12.6	9.9
17	14.3	9.3	14.1	9.5	13.9	9.8	13.8	10.0	13.6	10.2	13.4	10.5
18	15.1	9.8	14.9	10.1	14.7	10.3	14.6	10.6	14.4	10.8	14.2	11.1
19	15.9	10.3	15.8	10.6	15.6	10.9	15.4	11.2	15.2	11.4	15.0	11.7
20	16.8	10.9	16.6	11.2	16.4	11.5	16.2	11.8	16.0	12.0	15.8	12.3
21	17.6	11.4	17.4	11.7	17.2	12.0	17.0	12.3	16.8	12.6	16.5	12.9
22	18.5	12.0	18.2	12.3	18.0	12.6	17.8	12.9	17.6	13.2	17.3	13.5
23	19.3	12.5	19.1	12.9	18.8	13.2	18.6	13.5	18.4	13.8	18.1	14.2
24	20.1	13.1	19.9	13.4	19.7	13.8	19.4	14.1	19.2	14.4	18.9	14.8
25	21.0	13.6	20.7	14.0	20.5	14.3	20.2	14.7	20.0	15.0	19.7	15.4
26	21.8	14.2	21.6	14.5	21.3	14.9	21.0	15.3	20.8	15.6	20.5	16.0
27	22.6	14.7	22.4	15.1	22.1	15.5	21.8	15.9	21.6	16.2	21.3	16.6
28	23.5	15.2	23.2	15.7	22.9	16.1	22.7	16.5	22.4	16.9	22.1	17.2
29	24.3	15.8	24.0	16.2	23.8	16.6	23.5	17.0	23.2	17.5	22.9	17.9
30	25.2	16.3	24.9	16.8	24.6	17.2	24.3	17.6	24.0	18.1	23.6	18.5
31	26.0	16.9	25.7	17.3	25.4	17.8	25.1	18.2	24.8	18.7	24.4	19.1
32	26.8	17.4	26.5	17.9	26.2	18.4	25.9	18.8	25.6	19.3	25.2	19.7
33	27.7	18.0	27.4	18.5	27.0	18.9	26.7	19.4	26.4	19.9	26.0	20.3
34	28.5	18.5	28.2	19.0	27.9	19.5	27.5	20.0	27.2	20.5	26.8	20.9
35	29.4	19.1	29.0	19.6	28.7	20.1	28.3	20.6	28.0	21.1	27.6	21.5
36	30.2	19.6	29.8	20.1	29.5	20.6	29.1	21.2	28.8	21.7	28.4	22.2
37	31.0	20.2	30.7	20.7	30.3	21.2	29.9	21.7	29.5	22.3	29.2	22.8
38	31.9	20.7	31.5	21.2	31.1	21.8	30.7	22.3	30.3	22.9	29.9	23.4
39	32.7	21.2	32.3	21.8	31.9	22.4	31.6	22.9	31.1	23.5	30.7	24.0
40	33.5	21.8	33.2	22.4	32.8	22.9	32.4	23.5	31.9	24.1	31.5	24.6
41	34.4	22.3	34.0	22.9	33.6	23.5	33.2	24.1	32.7	24.7	32.3	25.2
42	35.2	22.9	34.8	23.5	34.4	24.1	34.0	24.7	33.5	25.3	33.1	25.9
43	36.1	23.4	35.6	24.0	35.2	24.7	34.8	25.3	34.3	25.9	33.9	26.5
44	36.9	24.0	36.5	24.6	36.0	25.2	35.6	25.9	35.1	26.5	34.7	27.1
45	37.7	24.5	37.3	25.2	36.9	25.8	36.4	26.5	35.9	27.1	35.5	27.7
46	38.6	25.1	38.1	25.7	37.7	26.4	37.2	27.0	36.7	27.7	36.2	28.3
47	39.4	25.6	39.0	26.3	38.5	27.0	38.0	27.6	37.5	28.3	37.0	28.9
48	40.3	26.1	39.8	26.8	39.3	27.5	38.8	28.2	38.3	28.9	37.8	29.6
49	41.1	26.7	40.6	27.4	40.1	28.1	39.6	28.8	39.1	29.5	38.6	30.2
50	41.9	27.2	41.5	28.0	41.0	28.7	40.5	29.4	39.9	30.1	39.4	30.8
100	83.9	54.5	82.9	55.9	81.9	57.4	80.9	58.8	79.9	60.2	78.8	61.6
200	167.7	108.9	165.8	111.8	163.8	114.7	161.8	117.6	159.7	120.4	157.6	123.1
300	251.6	163.4	248.7	167.8	245.7	172.1	242.7	176.3	239.6	180.5	236.4	184.7
400	335.5	217.8	331.6	223.7	327.7	229.4	323.6	235.1	319.4	240.7	315.2	246.3
500	419.3	272.3	414.5	279.6	409.6	286.8	404.5	293.9	399.3	300.9	394.0	307.8
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.
	(123°, 237°, 303°) 57°		(124°, 236°, 304°) 5 Pt. 56°		(125°, 235°, 305°) 55°		(126°, 234°, 306°) 54°		(127°, 233°, 307°) $4\frac{3}{4}$ Pt. 53°		(128°, 232°, 308°) 52°	

The 3-Pt. or 34° Courses are: N.E. by N., N.W. by N., S.E. by S., S.W. by S.

Dist.	33° (147°, 213°, 327°)		3 Pt. 34° (146°, 214°, 326°)		35° (145°, 215°, 325°)		36° (144°, 216°, 324°)		$3\frac{1}{4}$ Pt. 37° (143°, 217°, 323°)		38° (142°, 218°, 322°)	
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.
51	42.8	27.8	42.3	28.5	41.8	29.3	41.3	30.0	40.7	30.7	40.2	31.4
52	43.6	28.3	43.1	29.1	42.6	29.8	42.1	30.6	41.5	31.3	41.0	32.0
53	44.4	28.9	43.9	29.6	43.4	30.4	42.9	31.2	42.3	31.9	41.8	32.6
54	45.3	29.4	44.8	30.2	44.2	31.0	43.7	31.7	43.1	32.5	42.6	33.2
55	46.1	30.0	45.6	30.8	45.1	31.5	44.5	32.3	43.9	33.1	43.3	33.9
56	47.0	30.5	46.4	31.3	45.9	32.1	45.3	32.9	44.7	33.7	44.1	34.5
57	47.8	31.0	47.3	31.9	46.7	32.7	46.1	33.5	45.5	34.3	44.9	35.1
58	48.6	31.6	48.1	32.4	47.5	33.3	46.9	34.1	46.3	34.9	45.7	35.7
59	49.5	32.1	48.9	33.0	48.3	33.8	47.7	34.7	47.1	35.5	46.5	36.3
60	50.3	32.7	49.7	33.6	49.1	34.4	48.5	35.3	47.9	36.1	47.3	36.9
61	51.2	33.2	50.6	34.1	50.0	35.0	49.4	35.9	48.7	36.7	48.1	37.6
62	52.0	33.8	51.4	34.7	50.8	35.6	50.2	36.4	49.5	37.3	48.9	38.2
63	52.8	34.3	52.2	35.2	51.6	36.1	51.0	37.0	50.3	37.9	49.6	38.8
64	53.7	34.9	53.1	35.8	52.4	36.7	51.8	37.6	51.1	38.5	50.4	39.4
65	54.5	35.4	53.9	36.3	53.2	37.3	52.6	38.2	51.9	39.1	51.2	40.0
66	55.4	35.9	54.7	36.9	54.1	37.9	53.4	38.8	52.7	39.7	52.0	40.6
67	56.2	36.5	55.5	37.5	54.9	38.4	54.2	39.4	53.5	40.3	52.8	41.2
68	57.0	37.0	56.4	38.0	55.7	39.0	55.0	40.0	54.3	40.9	53.6	41.9
69	57.9	37.6	57.2	38.6	56.5	39.6	55.8	40.6	55.1	41.5	54.4	42.5
70	58.7	38.1	58.0	39.1	57.3	40.2	56.6	41.1	55.9	42.1	55.2	43.1
71	59.5	38.7	58.9	39.7	58.2	40.7	57.4	41.7	56.7	42.7	55.9	43.7
72	60.4	39.2	59.7	40.3	59.0	41.3	58.2	42.3	57.5	43.3	56.7	44.3
73	61.2	39.8	60.5	40.8	59.8	41.9	59.1	42.9	58.3	43.9	57.5	44.9
74	62.1	40.3	61.3	41.4	60.6	42.4	59.9	43.5	59.1	44.5	58.3	45.6
75	62.9	40.8	62.2	41.9	61.4	43.0	60.7	44.1	59.9	45.1	59.1	46.2
76	63.7	41.4	63.0	42.5	62.3	43.6	61.5	44.7	60.7	45.7	59.9	46.8
77	64.6	41.9	63.8	43.1	63.1	44.2	62.3	45.3	61.5	46.3	60.7	47.4
78	65.4	42.5	64.7	43.6	63.9	44.7	63.1	45.8	62.3	46.9	61.5	48.0
79	66.3	43.0	65.5	44.2	64.7	45.3	63.9	46.4	63.1	47.5	62.3	48.6
80	67.1	43.6	66.3	44.7	65.5	45.9	64.7	47.0	63.9	48.1	63.0	49.3
81	67.9	44.1	67.2	45.3	66.4	46.5	65.5	47.6	64.7	48.7	63.8	49.9
82	68.8	44.7	68.0	45.9	67.2	47.0	66.3	48.2	65.5	49.3	64.6	50.5
83	69.6	45.2	68.8	46.4	68.0	47.6	67.1	48.8	66.3	50.0	65.4	51.1
84	70.4	45.7	69.6	47.0	68.8	48.2	68.0	49.4	67.1	50.6	66.2	51.7
85	71.3	46.3	70.5	47.5	69.6	48.8	68.8	50.0	67.9	51.2	67.0	52.3
86	72.1	46.8	71.3	48.1	70.4	49.3	69.6	50.5	68.7	51.8	67.8	52.9
87	73.0	47.4	72.1	48.6	71.3	49.9	70.4	51.1	69.5	52.4	68.6	53.6
88	73.8	47.9	73.0	49.2	72.1	50.5	71.2	51.7	70.3	53.0	69.3	54.2
89	74.6	48.5	73.8	49.8	72.9	51.0	72.0	52.3	71.1	53.6	70.1	54.8
90	75.5	49.0	74.6	50.3	73.7	51.6	72.8	52.9	71.9	54.2	70.9	55.4
91	76.3	49.6	75.4	50.9	74.5	52.2	73.6	53.5	72.7	54.8	71.7	56.0
92	77.2	50.1	76.3	51.4	75.4	52.8	74.4	54.1	73.5	55.4	72.5	56.6
93	78.0	50.7	77.1	52.0	76.2	53.3	75.2	54.7	74.3	56.0	73.3	57.3
94	78.8	51.2	77.9	52.6	77.0	53.9	76.0	55.3	75.1	56.6	74.1	57.9
95	79.7	51.7	78.8	53.1	77.8	54.5	76.9	55.8	75.9	57.2	74.9	58.5
96	80.5	52.3	79.6	53.7	78.6	55.1	77.7	56.4	76.7	57.8	75.6	59.1
97	81.4	52.8	80.4	54.2	79.5	55.6	78.5	57.0	77.5	58.4	76.4	59.7
98	82.2	53.4	81.2	54.8	80.3	56.2	79.3	57.6	78.3	59.0	77.2	60.3
99	83.0	53.9	82.1	55.4	81.1	56.8	80.1	58.2	79.1	59.6	78.0	61.0
100	83.9	54.5	82.9	55.9	81.9	57.4	80.9	58.8	79.9	60.2	78.8	61.6
600	503.2	326.8	497.4	335.5	491.5	344.1	485.4	352.7	479.2	361.1	472.8	369.4
700	587.0	381.3	580.3	391.4	573.5	401.5	566.2	411.4	559.0	421.3	551.6	430.8
800	671.0	435.7	663.3	447.4	655.4	458.8	647.3	470.2	638.9	481.5	630.4	492.5
900	754.8	490.1	746.1	503.2	737.2	516.2	728.1	528.9	718.6	541.7	709.1	554.0
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.
	(123°, 237°, 303°) 57°		(124°, 236°, 304°) 5 Pt. 56°		(125°, 235°, 305°) 55°		(126°, 234°, 306°) 54°		(127°, 233°, 307°) $4\frac{3}{4}$ Pt. 53°		(128°, 232°, 308°) 52°	

The 5-Pt. or 56° Courses are: N.E. by E., S.E. by E., N.W. by W., S.W. by W.

Table 1. Traverse Table

Dist.	3½ Pt. **39°** (141°, 219°, 321°)		**40°** (140°, 220°, 320°)		**41°** (139°, 221°, 319°)		3¾ Pt. **42°** (138°, 222°, 318°)		**43°** (137°, 223°, 317°)		**44°** (136°, 224°, 316°)		4 Pt. **45°** (135°, 225°, 315°)	
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.
1	0.8	0.6	0.8	0.6	0.8	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
2	1.6	1.3	1.5	1.3	1.5	1.3	1.5	1.3	1.5	1.4	1.4	1.4	1.4	1.4
3	2.3	1.9	2.3	1.9	2.3	2.0	2.2	2.0	2.2	2.0	2.2	2.1	2.1	2.1
4	3.1	2.5	3.1	2.6	3.0	2.6	3.0	2.7	2.9	2.7	2.9	2.8	2.8	2.8
5	3.9	3.1	3.8	3.2	3.8	3.3	3.7	3.3	3.7	3.4	3.6	3.5	3.5	3.5
6	4.7	3.8	4.6	3.9	4.5	3.9	4.5	4.0	4.4	4.1	4.3	4.2	4.2	4.2
7	5.4	4.4	5.4	4.5	5.3	4.6	5.2	4.7	5.1	4.8	5.0	4.9	4.9	4.9
8	6.2	5.0	6.1	5.1	6.0	5.2	5.9	5.4	5.9	5.5	5.8	5.6	5.7	5.7
9	7.0	5.7	6.9	5.8	6.8	5.9	6.7	6.0	6.6	6.1	6.5	6.3	6.4	6.4
10	7.8	6.3	7.7	6.4	7.5	6.6	7.4	6.7	7.3	6.8	7.2	6.9	7.1	7.1
11	8.5	6.9	8.4	7.1	8.3	7.2	8.2	7.4	8.0	7.5	7.9	7.6	7.8	7.8
12	9.3	7.6	9.2	7.7	9.1	7.9	8.9	8.0	8.8	8.2	8.6	8.3	8.5	8.5
13	10.1	8.2	10.0	8.4	9.8	8.5	9.7	8.7	9.5	8.9	9.4	9.0	9.2	9.2
14	10.9	8.8	10.7	9.0	10.6	9.2	10.4	9.4	10.2	9.5	10.1	9.7	9.9	9.9
15	11.7	9.4	11.5	9.6	11.3	9.8	11.1	10.0	11.0	10.2	10.8	10.4	10.6	10.6
16	12.4	10.1	12.3	10.3	12.1	10.5	11.9	10.7	11.7	10.9	11.5	11.1	11.3	11.3
17	13.2	10.7	13.0	10.9	12.8	11.2	12.6	11.4	12.4	11.6	12.2	11.8	12.0	12.0
18	14.0	11.3	13.8	11.6	13.6	11.8	13.4	12.0	13.2	12.3	12.9	12.5	12.7	12.7
19	14.8	12.0	14.6	12.2	14.3	12.5	14.1	12.7	13.9	13.0	13.7	13.2	13.4	13.4
20	15.5	12.6	15.3	12.9	15.1	13.1	14.9	13.4	14.6	13.6	14.4	13.9	14.1	14.1
21	16.3	13.2	16.1	13.5	15.8	13.8	15.6	14.1	15.4	14.3	15.1	14.6	14.8	14.8
22	17.1	13.8	16.9	14.1	16.6	14.4	16.3	14.7	16.1	15.0	15.8	15.3	15.6	15.6
23	17.9	14.5	17.6	14.8	17.4	15.1	17.1	15.4	16.8	15.7	16.5	16.0	16.3	16.3
24	18.7	15.1	18.4	15.4	18.1	15.7	17.8	16.1	17.6	16.4	17.3	16.7	17.0	17.0
25	19.4	15.7	19.2	16.1	18.9	16.4	18.6	16.7	18.3	17.0	18.0	17.4	17.7	17.7
26	20.2	16.4	19.9	16.7	19.6	17.1	19.3	17.4	19.0	17.7	18.7	18.1	18.4	18.4
27	21.0	17.0	20.7	17.4	20.4	17.7	20.1	18.1	19.7	18.4	19.4	18.8	19.1	19.1
28	21.8	17.6	21.4	18.0	21.1	18.4	20.8	18.7	20.5	19.1	20.1	19.5	19.8	19.8
29	22.5	18.3	22.2	18.6	21.9	19.0	21.6	19.4	21.2	19.8	20.9	20.1	20.5	20.5
30	23.3	18.9	23.0	19.3	22.6	19.7	22.3	20.1	21.9	20.5	21.6	20.8	21.2	21.2
31	24.1	19.5	23.7	19.9	23.4	20.3	23.0	20.7	22.7	21.1	22.3	21.5	21.9	21.9
32	24.9	20.1	24.5	20.6	24.2	21.0	23.8	21.4	23.4	21.8	23.0	22.2	22.6	22.6
33	25.6	20.8	25.3	21.2	24.9	21.6	24.5	22.1	24.1	22.5	23.7	22.9	23.3	23.3
34	26.4	21.4	26.0	21.9	25.7	22.3	25.3	22.8	24.9	23.2	24.5	23.6	24.0	24.0
35	27.2	22.0	26.8	22.5	26.4	23.0	26.0	23.4	25.6	23.9	25.2	24.3	24.7	24.7
36	28.0	22.7	27.6	23.1	27.2	23.6	26.8	24.1	26.3	24.6	25.9	25.0	25.5	25.5
37	28.8	23.3	28.3	23.8	27.9	24.3	27.5	24.8	27.1	25.2	26.6	25.7	26.2	26.2
38	29.5	23.9	29.1	24.4	28.7	24.9	28.2	25.4	27.8	25.9	27.3	26.4	26.9	26.9
39	30.3	24.5	29.9	25.1	29.4	25.6	29.0	26.1	28.5	26.6	28.1	27.1	27.6	27.6
40	31.1	25.2	30.6	25.7	30.2	26.2	29.7	26.8	29.3	27.3	28.8	27.8	28.3	28.3
41	31.9	25.8	31.4	26.4	30.9	26.9	30.5	27.4	30.0	28.0	29.5	28.5	29.0	29.0
42	32.6	26.4	32.2	27.0	31.7	27.6	31.2	28.1	30.7	28.6	30.2	29.2	29.7	29.7
43	33.4	27.1	32.9	27.6	32.5	28.2	32.0	28.8	31.4	29.3	30.9	29.9	30.4	30.4
44	34.2	27.7	33.7	28.3	33.2	28.9	32.7	29.4	32.2	30.0	31.7	30.6	31.1	31.1
45	35.0	28.3	34.5	28.9	34.0	29.5	33.4	30.1	32.9	30.7	32.4	31.3	31.8	31.8
46	35.7	28.9	35.2	29.6	34.7	30.2	34.2	30.8	33.6	31.4	33.1	32.0	32.5	32.5
47	36.5	29.6	36.0	30.2	35.5	30.8	34.9	31.4	34.4	32.1	33.8	32.6	33.2	33.2
48	37.3	30.2	36.8	30.9	36.2	31.5	35.7	32.1	35.1	32.7	34.5	33.3	33.9	33.9
49	38.1	30.8	37.5	31.5	37.0	32.1	36.4	32.8	35.8	33.4	35.2	34.0	34.6	34.6
50	38.9	31.5	38.3	32.1	37.7	32.8	37.2	33.5	36.6	34.1	36.0	34.7	35.4	35.4
100	77.7	62.9	76.6	64.3	75.5	65.6	74.3	66.9	73.1	68.2	71.9	69.5	70.7	70.7
200	155.4	125.9	153.2	128.6	150.9	131.2	148.6	133.8	146.3	136.4	143.9	138.9	141.4	141.4
300	233.1	188.8	229.8	192.8	226.4	196.8	222.9	200.7	219.4	204.6	215.8	208.4	212.1	212.1
400	310.9	251.7	306.4	257.1	301.9	262.4	297.3	267.7	292.6	272.8	287.7	277.9	282.8	282.8
500	388.6	314.7	383.0	321.4	377.3	328.0	371.6	334.6	365.7	341.0	359.7	347.3	353.5	353.5
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.
	(129°, 231°, 309°) 4½ Pt. **51°**		(130°, 230°, 310°) **50°**		(131°, 229°, 311° **49°**		(132°, 228°, 312°) 4¼ Pt. **48°**		(133°, 227°, 313°) **47°**		(134°, 226°, 314°) **46°**		(135°, 225°, 315°) 4 Pt. **45°**	

The 4-Pt. or 45° Courses are: N.E., N.W., S.E., S.W.

Dist.	3½ Pt. **39°** (141°, 219°, 321°)		**40°** (140°, 220°, 320°)		**41°** (139°, 221°, 319°)		3¾ Pt. **42°** (138°, 222°, 318°)		**43°** (137°, 223°, 317°)		**44°** (136°, 224°, 316°)		4 Pt. **45°** (135°, 225°, 315°)	
	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.
51	39.6	32.1	39.1	32.8	38.5	33.5	37.9	34.1	37.3	34.8	36.7	35.4	36.1	36.1
52	40.4	32.7	39.8	33.4	39.2	34.1	38.6	34.8	38.0	35.5	37.4	36.1	36.8	36.8
53	41.2	33.4	40.6	34.1	40.0	34.8	39.4	35.5	38.8	36.1	38.1	36.8	37.5	37.5
54	42.0	34.0	41.4	34.7	40.8	35.4	40.1	36.1	39.5	36.8	38.8	37.5	38.2	38.2
55	42.7	34.6	42.1	35.4	41.5	36.1	40.9	36.8	40.2	37.5	39.6	38.2	38.9	38.9
56	43.5	35.2	42.9	36.0	42.3	36.7	41.6	37.5	41.0	38.2	40.3	38.9	39.6	39.6
57	44.3	35.9	43.7	36.6	43.0	37.4	42.4	38.1	41.7	38.9	41.0	39.6	40.3	40.3
58	45.1	36.5	44.4	37.3	43.8	38.1	43.1	38.8	42.4	39.6	41.7	40.3	41.0	41.0
59	45.9	37.1	45.2	37.9	44.5	38.7	43.8	39.5	43.1	40.2	42.4	41.0	41.7	41.7
60	46.6	37.8	46.0	38.6	45.3	39.4	44.6	40.1	43.9	40.9	43.2	41.7	42.4	42.4
61	47.4	38.4	46.7	39.2	46.0	40.0	45.3	40.8	44.6	41.6	43.9	42.4	43.1	43.1
62	48.2	39.0	47.5	39.9	46.8	40.7	46.1	41.5	45.3	42.3	44.6	43.1	43.8	43.8
63	49.0	39.6	48.3	40.5	47.5	41.3	46.8	42.2	46.1	43.0	45.3	43.8	44.5	44.5
64	49.7	40.3	49.0	41.1	48.3	42.0	47.6	42.8	46.8	43.6	46.0	44.5	45.3	45.3
65	50.5	40.9	49.8	41.8	49.1	42.6	48.3	43.5	47.5	44.3	46.8	45.2	46.0	46.0
66	51.3	41.5	50.6	42.4	49.8	43.3	49.0	44.2	48.3	45.0	47.5	45.8	46.7	46.7
67	52.1	42.2	51.3	43.1	50.6	44.0	49.8	44.8	49.0	45.7	48.2	46.5	47.4	47.4
68	52.8	42.8	52.1	43.7	51.3	44.6	50.5	45.5	49.7	46.4	48.9	47.2	48.1	48.1
69	53.6	43.4	52.9	44.4	52.1	45.3	51.3	46.2	50.5	47.1	49.6	47.9	48.8	48.8
70	54.4	44.1	53.6	45.0	52.8	45.9	52.0	46.8	51.2	47.7	50.4	48.6	49.5	49.5
71	55.2	44.7	54.4	45.6	53.6	46.6	52.8	47.5	51.9	48.4	51.1	49.3	50.2	50.2
72	56.0	45.3	55.2	46.3	54.3	47.2	53.5	48.2	52.7	49.1	51.8	50.0	50.9	50.9
73	56.7	45.9	55.9	46.9	55.1	47.9	54.2	48.8	53.4	49.8	52.5	50.7	51.6	51.6
74	57.5	46.6	56.7	47.6	55.8	48.5	55.0	49.5	54.1	50.5	53.2	51.4	52.3	52.3
75	58.3	47.2	57.5	48.2	56.6	49.2	55.7	50.2	54.9	51.1	54.0	52.1	53.0	53.0
76	59.1	47.8	58.2	48.9	57.4	49.9	56.5	50.9	55.6	51.8	54.7	52.8	53.7	53.7
77	59.8	48.5	59.0	49.5	58.1	50.5	57.2	51.5	56.3	52.5	55.4	53.5	54.4	54.4
78	60.6	49.1	59.8	50.1	58.9	51.2	58.0	52.2	57.0	53.2	56.1	54.2	55.2	55.2
79	61.4	49.7	60.5	50.8	59.6	51.8	58.7	52.9	57.8	53.9	56.8	54.9	55.9	55.9
80	62.2	50.3	61.3	51.4	60.4	52.5	59.5	53.5	58.5	54.6	57.5	55.6	56.6	56.6
81	62.9	51.0	62.0	52.1	61.1	53.1	60.2	54.2	59.2	55.2	58.3	56.3	57.3	57.3
82	63.7	51.6	62.8	52.7	61.9	53.8	60.9	54.9	60.0	55.9	59.0	57.0	58.0	58.0
83	64.5	52.2	63.6	53.4	62.6	54.5	61.7	55.5	60.7	56.6	59.7	57.7	58.7	58.7
84	65.3	52.9	64.3	54.0	63.4	55.1	62.4	56.2	61.4	57.3	60.4	58.4	59.4	59.4
85	66.1	53.5	65.1	54.6	64.2	55.8	63.2	56.9	62.2	58.0	61.1	59.0	60.1	60.1
86	66.8	54.1	65.9	55.3	64.9	56.4	63.9	57.5	62.9	58.7	61.9	59.7	60.8	60.8
87	67.6	54.8	66.6	55.9	65.7	57.1	64.7	58.2	63.6	59.3	62.6	60.4	61.5	61.5
88	68.4	55.4	67.4	56.6	66.4	57.7	65.4	58.9	64.4	60.0	63.3	61.1	62.2	62.2
89	69.2	56.0	68.2	57.2	67.2	58.4	66.1	59.6	65.1	60.7	64.0	61.8	62.9	62.9
90	69.9	56.6	68.9	57.9	67.9	59.0	66.9	60.2	65.8	61.4	64.7	62.5	63.6	63.6
91	70.7	57.3	69.7	58.5	68.7	59.7	67.6	60.9	66.6	62.1	65.5	63.2	64.3	64.3
92	71.5	57.9	70.5	59.1	69.4	60.4	68.4	61.6	67.3	62.7	66.2	63.9	65.1	65.1
93	72.3	58.5	71.2	59.8	70.2	61.0	69.1	62.2	68.0	63.4	66.9	64.6	65.8	65.8
94	73.1	59.2	72.0	60.4	70.9	61.7	69.9	62.9	68.7	64.1	67.6	65.3	66.5	66.5
95	73.8	59.8	72.8	61.1	71.7	62.3	70.6	63.6	69.5	64.8	68.3	66.0	67.2	67.2
96	74.6	60.4	73.5	61.7	72.5	63.0	71.3	64.2	70.2	65.5	69.1	66.7	67.9	67.9
97	75.4	61.0	74.3	62.4	73.2	63.6	72.1	64.9	70.9	66.2	69.8	67.4	68.6	68.6
98	76.2	61.7	75.1	63.0	74.0	64.3	72.8	65.6	71.7	66.8	70.5	68.1	69.3	69.3
99	76.9	62.3	75.8	63.6	74.7	64.9	73.6	66.2	72.4	67.5	71.2	68.8	70.0	70.0
100	77.7	62.9	76.6	64.3	75.5	65.6	74.3	66.9	73.1	68.2	71.9	69.5	70.7	70.7
600	466.3	377.6	459.6	385.7	452.8	393.6	445.9	401.5	438.8	409.2	431.6	416.8	424.3	424.3
700	543.9	440.6	536.3	450.0	528.3	459.2	520.2	468.4	511.9	477.4	503.5	486.3	495.0	495.0
800	621.8	503.5	613.0	514.2	603.9	524.8	594.6	535.3	585.1	545.6	575.4	555.8	565.7	565.7
900	699.3	566.3	689.5	578.5	679.2	590.3	668.8	602.2	658.2	613.8	647.3	625.2	636.3	636.3
	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.	Dep.	Lat.
	(129°, 231°, 309°) 4½ Pt. **51°**		(130°, 230°, 310°) **50°**		(131°, 229°, 311°) **49°**		(132°, 228°, 312°) 4¼ Pt. **48°**		(133°, 227°, 313°) **47°**		(134°, 226°, 314°) **46°**		(135°, 225°, 315°) 4 Pt. **45°**	

The 4-Pt. or 45° Courses are: N.E., N.W., S.E., S.W.

Table 2

To Change Long. Diff. into Dep., **subtract** Tabular Number from Long. Diff.

Long. Diff. or Dep.	Middle Latitude														
	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°	15°
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1
3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1
4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.2
6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2
7	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2
8	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.3
9	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3
10	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.3
11	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.4
12	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4
13	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.4
14	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5
15	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5
16	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.4	0.5	0.5
17	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.4	0.5	0.6
18	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.5	0.6
19	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.6	0.6
20	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.7
21	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.5	0.6	0.7
22	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.6	0.7	0.7
23	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.6	0.7	0.8
24	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.8
25	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.5	0.6	0.7	0.9
26	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.3	0.3	0.4	0.5	0.6	0.7	0.8	0.9
27	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.3	0.3	0.4	0.5	0.6	0.7	0.8	0.9
28	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.3	0.4	0.5	0.6	0.7	0.8	1.0
29	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.4	0.4	0.5	0.6	0.7	0.9	1.0
30	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
31	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.1
32	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.7	0.8	1.0	1.1
33	0.0	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.7	0.8	1.0	1.1
34	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.3	0.4	0.5	0.6	0.7	0.9	1.0	1.2
35	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.3	0.4	0.5	0.6	0.8	0.9	1.0	1.2
36	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.4	0.4	0.5	0.7	0.8	0.9	1.1	1.2
37	0.0	0.0	0.1	0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.1	1.3
38	0.0	0.0	0.1	0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	1.0	1.1	1.3
39	0.0	0.0	0.1	0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.9	1.0	1.2	1.3
40	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.7	0.9	1.0	1.2	1.4
41	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8	0.9	1.1	1.2	1.4
42	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.8	0.9	1.1	1.2	1.4
43	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.7	0.8	0.9	1.1	1.3	1.5
44	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.4	0.5	0.7	0.8	1.0	1.1	1.3	1.5
45	0.0	0.0	0.1	0.1	0.2	0.2	0.3	0.4	0.6	0.7	0.8	1.0	1.2	1.3	1.5
46	0.0	0.0	0.1	0.1	0.2	0.3	0.3	0.4	0.6	0.7	0.8	1.0	1.2	1.4	1.6
47	0.0	0.0	0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.9	1.0	1.2	1.4	1.6
48	0.0	0.0	0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.9	1.0	1.2	1.4	1.6
49	0.0	0.0	0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.9	1.1	1.3	1.5	1.7
50	0.0	0.0	0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.8	0.9	1.1	1.3	1.5	1.7
100	0.0	0.1	0.1	0.2	0.4	0.5	0.7	1.0	1.2	1.5	1.8	2.2	2.6	3.0	3.4
200	0.0	0.1	0.3	0.5	0.8	1.1	1.5	1.9	2.5	3.0	3.7	4.4	5.1	5.9	6.8
300	0.0	0.2	0.4	0.7	1.1	1.6	2.2	2.9	3.7	4.6	5.5	6.6	7.7	8.9	10.2
400	0.1	0.2	0.6	1.0	1.5	2.2	3.0	3.9	4.9	6.1	7.4	8.7	10.2	11.9	13.7
500	0.1	0.3	0.7	1.2	1.9	2.7	3.7	4.9	6.2	7.6	9.2	10.9	12.8	14.9	17.0
Factor	1.00	1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.01	1.02	1.02	1.02	1.03	1.03	1.04

To Change Dep. into Long. Diff., Multiply Tabular Number by Factor at Foot of Column, and **add** Product to Dep.

TO CHANGE LONG. DIFF. INTO DEP. **SUBTRACT** TABULAR NUMBER FROM LONG. DIFF.

LONG. DIFF. OR DEP.	MIDDLE LATITUDE														
	1°	2°	3°	4°	5°	6°	7°	8°	9°	10°	11°	12°	13°	14°	15°
51	0.0	0.0	0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.8	0.9	1.1	1.3	1.5	1.7
52	0.0	0.0	0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.8	1.0	1.1	1.3	1.5	1.8
53	0.0	0.0	0.1	0.1	0.2	0.3	0.4	0.5	0.7	0.8	1.0	1.2	1.4	1.6	1.8
54	0.0	0.0	0.1	0.1	0.2	0.3	0.4	0.5	0.7	0.8	1.0	1.2	1.4	1.6	1.8
55	0.0	0.0	0.1	0.1	0.2	0.3	0.4	0.5	0.7	0.8	1.0	1.2	1.4	1.6	1.9
56	0.0	0.0	0.1	0.1	0.2	0.3	0.4	0.5	0.7	0.9	1.0	1.2	1.4	1.7	1.9
57	0.0	0.0	0.1	0.1	0.2	0.3	0.4	0.6	0.7	0.9	1.0	1.2	1.5	1.7	1.9
58	0.0	0.0	0.1	0.1	0.2	0.3	0.4	0.6	0.7	0.9	1.1	1.3	1.5	1.7	2.0
59	0.0	0.0	0.1	0.1	0.2	0.3	0.4	0.6	0.7	0.9	1.1	1.3	1.5	1.8	2.0
60	0.0	0.0	0.1	0.1	0.2	0.3	0.4	0.6	0.7	0.9	1.1	1.3	1.5	1.8	2.0
61	0.0	0.0	0.1	0.1	0.2	0.3	0.5	0.6	0.8	0.9	1.1	1.3	1.6	1.8	2.1
62	0.0	0.0	0.1	0.2	0.2	0.3	0.5	0.6	0.8	0.9	1.1	1.4	1.6	1.8	2.1
63	0.0	0.0	0.1	0.2	0.2	0.3	0.5	0.6	0.8	1.0	1.2	1.4	1.6	1.9	2.1
64	0.0	0.0	0.1	0.2	0.2	0.4	0.5	0.6	0.8	1.0	1.2	1.4	1.6	1.9	2.2
65	0.0	0.0	0.1	0.2	0.2	0.4	0.5	0.6	0.8	1.0	1.2	1.4	1.7	1.9	2.2
66	0.0	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.8	1.0	1.2	1.4	1.7	2.0	2.2
67	0.0	0.0	0.1	0.2	0.3	0.4	0.5	0.7	0.8	1.0	1.2	1.5	1.7	2.0	2.3
68	0.0	0.0	0.1	0.2	0.3	0.4	0.5	0.7	0.8	1.0	1.2	1.5	1.7	2.0	2.3
69	0.0	0.0	0.1	0.2	0.3	0.4	0.5	0.7	0.8	1.0	1.3	1.5	1.8	2.0	2.4
70	0.0	0.0	0.1	0.2	0.3	0.4	0.5	0.7	0.9	1.1	1.3	1.5	1.8	2.1	2.4
71	0.0	0.0	0.1	0.2	0.3	0.4	0.5	0.7	0.9	1.1	1.3	1.6	1.8	2.1	2.4
72	0.0	0.0	0.1	0.2	0.3	0.4	0.5	0.7	0.9	1.1	1.3	1.6	1.8	2.1	2.5
73	0.0	0.0	0.1	0.2	0.3	0.4	0.5	0.7	0.9	1.1	1.3	1.6	1.9	2.2	2.5
74	0.0	0.0	0.1	0.2	0.3	0.4	0.6	0.7	0.9	1.1	1.4	1.6	1.9	2.2	2.5
75	0.0	0.0	0.1	0.2	0.3	0.4	0.6	0.7	0.9	1.1	1.4	1.6	1.9	2.2	2.6
76	0.0	0.0	0.1	0.2	0.3	0.4	0.6	0.7	0.9	1.2	1.4	1.7	1.9	2.3	2.6
77	0.0	0.0	0.1	0.2	0.3	0.4	0.6	0.7	0.9	1.2	1.4	1.7	2.0	2.3	2.6
78	0.0	0.0	0.1	0.2	0.3	0.4	0.6	0.8	1.0	1.2	1.4	1.7	2.0	2.3	2.7
79	0.0	0.0	0.1	0.2	0.3	0.4	0.6	0.8	1.0	1.2	1.5	1.7	2.0	2.3	2.7
80	0.0	0.0	0.1	0.2	0.3	0.4	0.6	0.8	1.0	1.2	1.5	1.7	2.1	2.4	2.7
81	0.0	0.0	0.1	0.2	0.3	0.4	0.6	0.8	1.0	1.2	1.5	1.8	2.1	2.4	2.8
82	0.0	0.0	0.1	0.2	0.3	0.4	0.6	0.8	1.0	1.2	1.5	1.8	2.1	2.4	2.8
83	0.0	0.1	0.1	0.2	0.3	0.5	0.6	0.8	1.0	1.3	1.5	1.8	2.1	2.5	2.8
84	0.0	0.1	0.1	0.2	0.3	0.5	0.6	0.8	1.0	1.3	1.5	1.8	2.2	2.5	2.9
85	0.0	0.1	0.1	0.2	0.3	0.5	0.6	0.8	1.0	1.3	1.6	1.9	2.2	2.5	2.9
86	0.0	0.1	0.1	0.2	0.3	0.5	0.6	0.8	1.1	1.3	1.6	1.9	2.2	2.6	2.9
87	0.0	0.1	0.1	0.2	0.3	0.5	0.6	0.8	1.1	1.3	1.6	1.9	2.2	2.6	3.0
88	0.0	0.1	0.1	0.2	0.3	0.5	0.7	0.9	1.1	1.3	1.6	1.9	2.3	2.6	3.0
89	0.0	0.1	0.1	0.2	0.3	0.5	0.7	0.9	1.1	1.4	1.6	1.9	2.3	2.6	3.0
90	0.0	0.1	0.1	0.2	0.3	0.5	0.7	0.9	1.1	1.4	1.7	2.0	2.3	2.7	3.1
91	0.0	0.1	0.1	0.2	0.3	0.5	0.7	0.9	1.1	1.4	1.7	2.0	2.3	2.7	3.1
92	0.0	0.1	0.1	0.2	0.4	0.5	0.7	0.9	1.1	1.4	1.7	2.0	2.4	2.7	3.1
93	0.0	0.1	0.1	0.2	0.4	0.5	0.7	0.9	1.1	1.4	1.7	2.0	2.4	2.8	3.2
94	0.0	0.1	0.1	0.2	0.4	0.5	0.7	0.9	1.2	1.4	1.7	2.1	2.4	2.8	3.2
95	0.0	0.1	0.1	0.2	0.4	0.5	0.7	0.9	1.2	1.4	1.7	2.1	2.4	2.8	3.2
96	0.0	0.1	0.1	0.2	0.4	0.5	0.7	0.9	1.2	1.5	1.8	2.1	2.5	2.9	3.3
97	0.0	0.1	0.1	0.2	0.4	0.5	0.7	0.9	1.2	1.5	1.8	2.1	2.5	2.9	3.3
98	0.0	0.1	0.1	0.2	0.4	0.5	0.7	1.0	1.2	1.5	1.8	2.1	2.5	2.9	3.3
99	0.0	0.1	0.1	0.2	0.4	0.5	0.7	1.0	1.2	1.5	1.8	2.2	2.5	2.9	3.4
100	0.0	0.1	0.1	0.2	0.4	0.5	0.7	1.0	1.2	1.5	1.8	2.2	2.6	3.0	3.4
600	0.1	0.4	0.8	1.4	2.3	3.3	4.5	5.8	7.4	9.1	10.0	13.1	15.4	17.8	20.5
700	0.2	0.5	1.0	1.8	2.8	3.9	5.1	6.7	8.7	10.5	12.9	15.3	17.9	20.8	23.9
800	0.2	0.5	1.1	2.0	3.1	4.4	5.9	7.7	9.8	12.1	14.8	17.5	20.6	23.8	27.3
900	0.3	0.7	1.4	2.4	3.6	5.0	6.7	8.7	11.2	13.7	16.7	19.8	23.2	26.8	30.8
	1.00	1.00	1.00	1.00	1.00	1.01	1.01	1.01	1.01	1.02	1.02	1.02	1.03	1.03	1.04
	FACTOR														

TO CHANGE DEP. INTO LONG. DIFF. MULTIPLY TABULAR NUMBER BY FACTOR AT FOOT OF COLUMN AND **ADD** PRODUCT TO DEP.

Table 2

To Change Long. Diff. into Dep., **subtract** Tabular Number from Long. Diff.

Long. Diff. or Dep.	Middle Latitude												
	16°	**17°**	**18°**	**19°**	**20°**	**21°**	**22°**	**23°**	**24°**	**25°**	**26°**	**27°**	**28°**
1	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2
3	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.4
4	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.5
5	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.5	0.6
6	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7
7	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.8
8	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.9	0.9
9	0.3	0.4	0.4	0.5	0.5	0.6	0.7	0.7	0.8	0.8	0.9	1.0	1.1
10	0.4	0.4	0.5	0.5	0.6	0.7	0.7	0.8	0.9	0.9	1.0	1.1	1.2
11	0.4	0.5	0.5	0.6	0.7	0.7	0.8	0.9	1.0	1.0	1.1	1.2	1.3
12	0.5	0.5	0.6	0.7	0.7	0.8	0.9	1.0	1.0	1.1	1.2	1.3	1.4
13	0.5	0.6	0.6	0.7	0.8	0.9	0.9	1.0	1.1	1.2	1.3	1.4	1.5
14	0.5	0.6	0.7	0.8	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6
15	0.6	0.7	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.8
16	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.9
17	0.7	0.7	0.8	0.9	1.0	1.1	1.2	1.4	1.5	1.6	1.7	1.9	2.0
18	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.6	1.7	1.8	2.0	2.1
19	0.7	0.8	0.9	1.0	1.1	1.3	1.4	1.5	1.6	1.8	1.9	2.1	2.2
20	0.8	0.9	1.0	1.1	1.2	1.3	1.5	1.6	1.7	1.9	2.0	2.2	2.3
21	0.8	0.9	1.0	1.1	1.3	1.4	1.5	1.7	1.8	2.0	2.1	2.3	2.5
22	0.9	1.0	1.1	1.2	1.3	1.5	1.6	1.7	1.9	2.1	2.2	2.4	2.6
23	0.9	1.0	1.1	1.3	1.4	1.5	1.7	1.8	2.0	2.2	2.3	2.5	2.7
24	0.9	1.0	1.2	1.3	1.4	1.6	1.7	1.9	2.1	2.2	2.4	2.6	2.8
25	1.0	1.1	1.2	1.4	1.5	1.7	1.8	2.0	2.2	2.3	2.5	2.7	2.9
26	1.0	1.1	1.3	1.4	1.6	1.7	1.9	2.1	2.2	2.4	2.6	2.8	3.0
27	1.0	1.2	1.3	1.5	1.6	1.8	2.0	2.1	2.3	2.5	2.7	2.9	3.2
28	1.1	1.2	1.4	1.5	1.7	1.9	2.0	2.2	2.4	2.6	2.8	3.1	3.3
29	1.1	1.3	1.4	1.6	1.7	1.9	2.1	2.3	2.5	2.7	2.9	3.2	3.4
30	1.2	1.3	1.5	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.3	3.5
31	1.2	1.4	1.5	1.7	1.9	2.1	2.3	2.5	2.7	2.9	3.1	3.4	3.6
32	1.2	1.4	1.6	1.7	1.9	2.1	2.3	2.5	2.8	3.0	3.2	3.5	3.7
33	1.3	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.9	3.1	3.3	3.6	3.9
34	1.3	1.5	1.7	1.9	2.1	2.3	2.5	2.7	2.9	3.2	3.4	3.7	4.0
35	1.4	1.5	1.7	1.9	2.1	2.3	2.5	2.8	3.0	3.3	3.5	3.8	4.1
36	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.9	3.1	3.4	3.6	3.9	4.2
37	1.4	1.6	1.8	2.0	2.2	2.5	2.7	2.9	3.2	3.5	3.7	4.0	4.3
38	1.5	1.7	1.9	2.1	2.3	2.5	2.8	3.0	3.3	3.6	3.8	4.1	4.4
39	1.5	1.7	1.9	2.1	2.4	2.6	2.8	3.1	3.4	3.7	3.9	4.3	4.6
40	1.5	1.7	2.0	2.2	2.4	2.7	2.9	3.2	3.5	3.7	4.0	4.4	4.7
41	1.6	1.8	2.0	2.2	2.5	2.7	3.0	3.3	3.5	3.8	4.1	4.5	4.8
42	1.6	1.8	2.1	2.3	2.5	2.8	3.1	3.3	3.6	3.9	4.3	4.6	4.9
43	1.7	1.9	2.1	2.3	2.6	2.9	3.1	3.4	3.7	4.0	4.4	4.7	5.0
44	1.7	1.9	2.2	2.4	2.7	2.9	3.2	3.5	3.8	4.1	4.5	4.8	5.2
45	1.7	2.0	2.2	2.5	2.7	3.0	3.3	3.6	3.9	4.2	4.6	4.9	5.3
46	1.8	2.0	2.3	2.5	2.8	3.1	3.3	3.7	4.0	4.3	4.7	5.0	5.4
47	1.8	2.1	2.3	2.6	2.8	3.1	3.4	3.7	4.1	4.4	4.8	5.1	5.5
48	1.9	2.1	2.3	2.6	2.9	3.2	3.5	3.8	4.1	4.5	4.9	5.2	5.6
49	1.9	2.1	2.4	2.7	3.0	3.3	3.6	3.9	4.2	4.6	5.0	5.3	5.7
50	1.9	2.2	2.4	2.7	3.0	3.3	3.6	4.0	4.3	4.7	5.1	5.4	5.9
100	3.9	4.4	4.9	5.4	6.0	6.6	7.3	7.9	8.6	9.4	10.1	10.9	11.7
200	7.7	8.7	9.8	10.9	12.1	13.3	14.6	15.9	17.3	18.7	20.2	21.8	23.4
300	11.6	13.1	14.7	16.3	18.1	19.9	21.8	23.8	25.9	28.1	30.4	32.7	35.1
400	15.5	17.5	19.6	21.8	24.1	26.6	29.1	31.8	34.6	37.5	40.5	43.6	46.9
500	19.4	21.9	24.5	27.2	30.1	33.2	36.4	39.8	43.2	46.9	50.6	54.5	58.5
	1.04	1.05	1.05	1.06	1.06	1.07	1.08	1.09	1.09	1.10	1.11	1.12	1.13
	Factor												

To Change Dep. into Long. Diff., Multiply Tabular Number by Factor at Foot of Column and **add** Product to Dep.

To Change Long. Diff. into Dep. **SUBTRACT** Tabular Number from Long. Diff.

Long. Diff. or Dep.	Middle Latitude 16°	17°	18°	19°	20°	21°	22°	23°	24°	25°	26°	27°	28°
51	2.0	2.2	2.5	2.8	3.1	3.4	3.7	4.1	4.4	4.8	5.2	5.6	6.0
52	2.0	2.3	2.5	2.8	3.1	3.5	3.8	4.1	4.5	4.9	5.3	5.7	6.1
53	2.1	2.3	2.6	2.9	3.2	3.5	3.9	4.2	4.6	5.0	5.4	5.8	6.2
54	2.1	2.4	2.6	2.9	3.3	3.6	3.9	4.3	4.7	5.1	5.5	5.9	6.3
55	2.1	2.4	2.7	3.0	3.3	3.7	4.0	4.4	4.8	5.2	5.6	6.0	6.4
56	2.2	2.4	2.7	3.1	3.4	3.7	4.1	4.5	4.8	5.2	5.7	6.1	6.6
57	2.2	2.5	2.8	3.1	3.4	3.8	4.2	4.5	4.9	5.3	5.8	6.2	6.7
58	2.2	2.5	2.8	3.2	3.5	3.9	4.2	4.6	5.0	5.4	5.9	6.3	6.8
59	2.3	2.6	2.9	3.2	3.6	3.9	4.3	4.7	5.1	5.5	6.0	6.4	6.9
60	2.3	2.6	2.9	3.3	3.6	4.0	4.4	4.8	5.2	5.6	6.1	6.5	7.0
61	2.4	2.7	3.0	3.3	3.7	4.1	4.4	4.8	5.3	5.7	6.2	6.6	7.1
62	2.4	2.7	3.0	3.4	3.7	4.1	4.5	4.9	5.4	5.8	6.3	6.8	7.3
63	2.4	2.8	3.1	3.4	3.8	4.2	4.6	5.0	5.4	5.9	6.4	6.9	7.4
64	2.5	2.8	3.1	3.5	3.9	4.3	4.7	5.1	5.5	6.0	6.5	7.0	7.5
65	2.5	2.8	3.2	3.5	3.9	4.3	4.7	5.2	5.6	6.1	6.6	7.1	7.6
66	2.6	2.9	3.2	3.6	4.0	4.4	4.8	5.2	5.7	6.2	6.7	7.2	7.7
67	2.6	2.9	3.3	3.7	4.0	4.5	4.9	5.3	5.8	6.3	6.8	7.3	7.8
68	2.6	3.0	3.3	3.7	4.1	4.5	5.0	5.4	5.9	6.4	6.9	7.4	8.0
69	2.7	3.0	3.4	3.8	4.2	4.6	5.0	5.5	6.0	6.5	7.0	7.5	8.1
70	2.7	3.1	3.4	3.8	4.2	4.6	5.1	5.6	6.1	6.6	7.1	7.6	8.2
71	2.8	3.1	3.5	3.9	4.3	4.7	5.2	5.6	6.1	6.7	7.2	7.7	8.3
72	2.8	3.1	3.5	3.9	4.3	4.8	5.2	5.7	6.2	6.7	7.3	7.8	8.4
73	2.8	3.2	3.6	4.0	4.4	4.8	5.3	5.8	6.3	6.8	7.4	8.0	8.5
74	2.9	3.2	3.6	4.0	4.5	4.9	5.4	5.9	6.4	6.9	7.5	8.1	8.7
75	2.9	3.3	3.7	4.1	4.5	5.0	5.5	6.0	6.5	7.0	7.6	8.2	8.8
76	2.9	3.3	3.7	4.1	4.6	5.0	5.5	6.0	6.6	7.1	7.7	8.3	8.9
77	3.0	3.4	3.8	4.2	4.6	5.1	5.6	6.1	6.7	7.2	7.8	8.4	9.0
78	3.0	3.4	3.8	4.2	4.7	5.2	5.7	6.2	6.7	7.3	7.9	8.5	9.1
79	3.1	3.5	3.9	4.3	4.8	5.2	5.8	6.3	6.8	7.4	8.0	8.6	9.2
80	3.1	3.5	3.9	4.4	4.8	5.3	5.8	6.4	6.9	7.5	8.1	8.7	9.4
81	3.1	3.5	4.0	4.4	4.9	5.4	5.9	6.4	7.0	7.6	8.2	8.8	9.5
82	3.2	3.6	4.0	4.5	4.9	5.4	6.0	6.5	7.1	7.7	8.3	8.9	9.6
83	3.2	3.6	4.1	4.5	5.0	5.5	6.0	6.6	7.2	7.8	8.4	9.0	9.7
84	3.3	3.7	4.1	4.6	5.1	5.6	6.1	6.7	7.3	7.9	8.5	9.2	9.8
85	3.3	3.7	4.2	4.6	5.1	5.6	6.2	6.8	7.3	8.0	8.6	9.3	9.9
86	3.3	3.8	4.2	4.7	5.2	5.7	6.3	6.8	7.4	8.1	8.7	9.4	10.1
87	3.4	3.8	4.3	4.7	5.2	5.8	6.3	6.9	7.5	8.2	8.8	9.5	10.2
88	3.4	3.8	4.3	4.8	5.3	5.8	6.4	7.0	7.6	8.2	8.9	9.6	10.3
89	3.4	3.9	4.4	4.8	5.4	5.9	6.5	7.1	7.7	8.3	9.0	9.7	10.4
90	3.5	3.9	4.4	4.9	5.4	6.0	6.6	7.2	7.8	8.4	9.1	9.8	10.5
91	3.5	4.0	4.5	5.0	5.5	6.0	6.6	7.2	7.9	8.5	9.2	9.9	10.7
92	3.6	4.0	4.5	5.0	5.5	6.1	6.7	7.3	8.0	8.6	9.3	10.0	10.8
93	3.6	4.1	4.6	5.1	5.6	6.2	6.8	7.4	8.0	8.7	9.4	10.1	10.9
94	3.6	4.1	4.6	5.1	5.7	6.2	6.8	7.5	8.1	8.8	9.5	10.2	11.0
95	3.7	4.2	4.6	5.2	5.7	6.3	6.9	7.6	8.2	8.9	9.6	10.4	11.1
96	3.7	4.2	4.7	5.2	5.8	6.4	7.0	7.6	8.3	9.0	9.7	10.5	11.2
97	3.8	4.2	4.7	5.3	5.8	6.4	7.1	7.7	8.4	9.1	9.8	10.6	11.4
98	3.8	4.3	4.8	5.3	5.9	6.5	7.1	7.8	8.5	9.2	9.9	10.7	11.5
99	3.8	4.3	4.8	5.4	6.0	6.6	7.2	7.9	8.6	9.3	10.0	10.8	11.6
100	3.9	4.4	4.9	5.4	6.0	6.6	7.3	7.9	8.6	9.4	10.1	10.9	11.7
600	23.2	26.2	29.4	32.7	36.2	39.9	43.7	47.7	51.9	56.2	60.7	65.4	70.2
700	27.2	30.6	34.2	38.1	42.1	46.4	50.9	55.7	60.5	65.5	70.8	76.3	82.0
800	31.0	35.0	39.2	43.5	48.2	53.1	58.2	63.6	69.2	74.9	80.9	87.1	93.7
900	35.0	39.4	44.1	49.1	54.3	59.7	65.5	71.7	77.9	84.4	91.1	98.1	105.5
Factor	1.04	1.05	1.05	1.06	1.06	1.07	1.08	1.09	1.10	1.10	1.11	1.12	1.13

To Change Dep. into Long. Diff. Multiply Tabular Number by Factor at Foot of Column, and **ADD** Product to Dep.

Table 2

To Change Long. Diff. into Dep., **subtract** Tabular Number from Long. Diff.

Long. Diff. or Dep.	Middle Latitude											
	29°	**30°**	**31°**	**32°**	**33°**	**34°**	**35°**	**36°**	**37°**	**38°**	**39°**	**40°**
1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
2	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.5
3	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.7	0.7
4	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.8	0.8	0.8	0.9	0.9
5	0.6	0.7	0.7	0.8	0.8	0.9	0.9	1.0	1.0	1.1	1.1	1.2
6	0.8	0.8	0.9	0.9	1.0	1.0	1.1	1.1	1.2	1.3	1.3	1.4
7	0.9	0.9	1.0	1.1	1.1	1.2	1.3	1.3	1.4	1.5	1.6	1.6
8	1.0	1.1	1.1	1.2	1.3	1.4	1.4	1.5	1.6	1.7	1.8	1.9
9	1.1	1.2	1.3	1.4	1.5	1.5	1.6	1.7	1.8	1.9	2.0	2.1
10	1.3	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3
11	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.1	2.2	2.3	2.5	2.6
12	1.5	1.6	1.7	1.8	1.9	2.1	2.2	2.3	2.4	2.5	2.7	2.8
13	1.6	1.7	1.9	2.0	2.1	2.2	2.4	2.5	2.6	2.8	2.9	3.0
14	1.8	1.9	2.0	2.1	2.3	2.4	2.5	2.7	2.8	3.0	3.1	3.3
15	1.9	2.0	2.1	2.3	2.4	2.6	2.7	2.9	3.0	3.2	3.3	3.5
16	2.0	2.1	2.3	2.4	2.6	2.7	2.9	3.1	3.2	3.4	3.6	3.7
17	2.1	2.3	2.4	2.6	2.7	2.9	3.1	3.2	3.4	3.6	3.8	4.0
18	2.3	2.4	2.6	2.7	2.9	3.1	3.3	3.4	3.6	3.8	4.0	4.2
19	2.4	2.5	2.7	2.9	3.1	3.2	3.4	3.6	3.8	4.0	4.2	4.4
20	2.5	2.7	2.9	3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.5	4.7
21	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.5	4.7	4.9
22	2.8	2.9	3.1	3.3	3.5	3.8	4.0	4.2	4.4	4.7	4.9	5.1
23	2.9	3.1	3.3	3.5	3.7	3.9	4.2	4.4	4.6	4.9	5.1	5.4
24	3.0	3.2	3.4	3.6	3.9	4.1	4.3	4.6	4.8	5.1	5.3	5.6
25	3.1	3.3	3.6	3.8	4.0	4.3	4.5	4.8	5.0	5.3	5.6	5.8
26	3.3	3.5	3.7	4.0	4.2	4.4	4.7	5.0	5.2	5.5	5.8	6.1
27	3.4	3.6	3.9	4.1	4.4	4.6	4.9	5.2	5.4	5.7	6.0	6.3
28	3.5	3.8	4.0	4.3	4.5	4.8	5.1	5.3	5.6	5.9	6.2	6.6
29	3.6	3.9	4.1	4.4	4.7	5.0	5.2	5.5	5.8	6.1	6.5	6.8
30	3.8	4.0	4.3	4.6	4.8	5.1	5.4	5.7	6.0	6.4	6.7	7.0
31	3.9	4.2	4.4	4.7	5.0	5.3	5.6	5.9	6.2	6.6	6.9	7.3
32	4.0	4.3	4.6	4.9	5.2	5.5	5.8	6.1	6.4	6.8	7.1	7.5
33	4.1	4.4	4.7	5.0	5.3	5.6	6.0	6.3	6.6	7.0	7.4	7.7
34	4.3	4.6	4.9	5.2	5.5	5.8	6.1	6.5	6.8	7.2	7.6	8.0
35	4.4	4.7	5.0	5.3	5.6	6.0	6.3	6.7	7.0	7.4	7.8	8.2
36	4.5	4.8	5.1	5.5	5.8	6.2	6.5	6.9	7.2	7.6	8.0	8.4
37	4.6	5.0	5.3	5.6	6.0	6.3	6.7	7.1	7.5	7.8	8.2	8.7
38	4.8	5.1	5.4	5.8	6.1	6.5	6.9	7.3	7.7	8.1	8.5	8.9
39	4.9	5.2	5.6	5.9	6.3	6.7	7.1	7.4	7.9	8.3	8.7	9.1
40	5.0	5.4	5.7	6.1	6.5	6.8	7.2	7.6	8.1	8.5	8.9	9.4
41	5.1	5.5	5.9	6.2	6.6	7.0	7.4	7.8	8.3	8.7	9.1	9.6
42	5.3	5.6	6.0	6.4	6.8	7.2	7.6	8.0	8.5	8.9	9.4	9.8
43	5.4	5.8	6.1	6.5	6.9	7.4	7.8	8.2	8.7	9.1	9.6	10.1
44	5.5	5.9	6.3	6.7	7.1	7.5	8.0	8.4	8.9	9.3	9.8	10.3
45	5.6	6.0	6.4	6.8	7.3	7.7	8.1	8.6	9.1	9.5	10.0	10.5
46	5.8	6.2	6.6	7.0	7.4	7.9	8.3	8.8	9.3	9.8	10.3	10.8
47	5.9	6.3	6.7	7.1	7.6	8.0	8.5	9.0	9.5	10.0	10.5	11.0
48	6.0	6.4	6.9	7.3	7.7	8.2	8.7	9.2	9.7	10.2	10.7	11.2
49	6.1	6.6	7.0	7.4	7.9	8.4	8.9	9.4	9.9	10.4	10.9	11.5
50	6.3	6.7	7.1	7.6	8.1	8.5	9.0	9.5	10.1	10.6	11.1	11.7
100	12.5	13.4	14.3	15.2	16.1	17.1	18.1	19.1	20.1	21.2	22.3	23.4
200	25.1	26.8	28.6	30.4	32.3	34.2	36.2	38.2	40.3	42.4	44.6	46.8
300	37.6	40.2	42.9	45.6	48.4	51.3	54.3	57.3	60.4	63.6	66.9	70.2
400	50.2	53.6	57.1	60.8	64.5	68.4	72.3	76.4	80.6	84.8	89.1	93.6
500	62.7	67.0	71.4	76.0	80.7	85.5	90.4	95.5	100.7	106.0	111.4	117.0
	1.14	1.15	1.17	1.18	1.19	1.21	1.22	1.24	1.25	1.27	1.29	1.31
	Factor											

To Change Dep. into Long. Diff., Multiply Tabular Number by Factor at Foot of Column, and **add** Product to Dep.

To Change Long. Diff. into Dep. **subtract** Tabular Number from Long. Diff.

Long. Diff. or Dep.	Middle Latitude											
	29°	**30°**	**31°**	**32°**	**33°**	**34°**	**35°**	**36°**	**37°**	**38°**	**39°**	**40°**
51	6.4	6.8	7.3	7.7	8.2	8.7	9.2	9.7	10.3	10.8	11.4	11.9
52	6.5	7.0	7.4	7.9	8.4	8.9	9.4	9.9	10.5	11.0	11.6	12.2
53	6.6	7.1	7.6	8.1	8.6	9.1	9.6	10.1	10.7	11.2	11.8	12.4
54	6.8	7.2	7.7	8.2	8.7	9.2	9.8	10.3	10.9	11.4	12.0	12.6
55	6.9	7.4	7.9	8.4	8.9	9.4	9.9	10.5	11.1	11.7	12.3	12.9
56	7.0	7.5	8.0	8.5	9.0	9.6	10.1	10.7	11.3	11.9	12.5	13.1
57	7.1	7.6	8.1	8.7	9.2	9.7	10.3	10.9	11.5	12.1	12.7	13.3
58	7.3	7.8	8.3	8.8	9.4	9.9	10.5	11.1	11.7	12.3	12.9	13.6
59	7.4	7.9	8.4	9.0	9.5	10.1	10.7	11.3	11.9	12.5	13.1	13.8
60	7.5	8.0	8.6	9.1	9.7	10.3	10.9	11.5	12.1	12.7	13.4	14.0
61	7.6	8.2	8.7	9.3	9.8	10.4	11.0	11.6	12.3	12.9	13.6	14.3
62	7.8	8.3	8.9	9.4	10.0	10.6	11.2	11.8	12.5	13.1	13.8	14.5
63	7.9	8.4	9.0	9.6	10.2	10.8	11.4	12.0	12.7	13.4	14.0	14.7
64	8.0	8.6	9.1	9.7	10.3	10.9	11.6	12.2	12.9	13.6	14.3	15.0
65	8.1	8.7	9.3	9.9	10.5	11.1	11.8	12.4	13.1	13.8	14.5	15.2
66	8.3	8.8	9.4	10.0	10.6	11.3	11.9	12.6	13.3	14.0	14.7	15.4
67	8.4	9.0	9.6	10.2	10.8	11.5	12.1	12.8	13.5	14.2	14.9	15.7
68	8.5	9.1	9.7	10.3	11.0	11.6	12.3	13.0	13.7	14.4	15.2	15.9
69	8.7	9.2	9.9	10.5	11.1	11.8	12.5	13.2	13.9	14.6	15.4	16.1
70	8.8	9.4	10.0	10.6	11.3	12.0	12.7	13.4	14.1	14.8	15.6	16.4
71	8.9	9.5	10.1	10.8	11.5	12.1	12.8	13.6	14.3	15.1	15.8	16.6
72	9.0	9.6	10.3	10.9	11.6	12.3	13.0	13.8	14.5	15.3	16.0	16.8
73	9.2	9.8	10.4	11.1	11.8	12.5	13.2	13.9	14.7	15.5	16.3	17.1
74	9.3	9.9	10.6	11.2	11.9	12.7	13.4	14.1	14.9	15.7	16.5	17.3
75	9.4	10.0	10.7	11.4	12.1	12.8	13.6	14.3	15.1	15.9	16.7	17.5
76	9.5	10.2	10.9	11.5	12.3	13.0	13.7	14.5	15.3	16.1	16.9	17.8
77	9.7	10.3	11.0	11.7	12.4	13.2	13.9	14.7	15.5	16.3	17.2	18.0
78	9.8	10.5	11.1	11.9	12.6	13.3	14.1	14.9	15.7	16.5	17.4	18.2
79	9.9	10.6	11.3	12.0	12.7	13.5	14.3	15.1	15.9	16.7	17.6	18.5
80	10.0	10.7	11.4	12.2	12.9	13.7	14.5	15.3	16.1	17.0	17.8	18.7
81	10.2	10.9	11.6	12.3	13.1	13.8	14.6	15.5	16.3	17.2	18.1	19.0
82	10.3	11.0	11.7	12.5	13.2	14.0	14.8	15.7	16.5	17.4	18.3	19.2
83	10.4	11.1	11.9	12.6	13.4	14.2	15.0	15.9	16.7	17.6	18.5	19.4
84	10.5	11.3	12.0	12.8	13.6	14.4	15.2	16.0	16.9	17.8	18.7	19.7
85	10.7	11.4	12.1	12.9	13.7	14.5	15.4	16.2	17.1	18.0	18.9	19.9
86	10.8	11.5	12.3	13.1	13.9	14.7	15.6	16.4	17.3	18.2	19.2	20.1
87	10.9	11.7	12.4	13.2	14.0	14.9	15.7	16.6	17.5	18.4	19.4	20.4
88	11.0	11.8	12.6	13.4	14.2	15.0	15.9	16.8	17.7	18.7	19.6	20.6
89	11.2	11.9	12.7	13.5	14.4	15.2	16.1	17.0	17.9	18.9	19.8	20.8
90	11.3	12.1	12.9	13.7	14.5	15.4	16.3	17.2	18.1	19.1	20.1	21.1
91	11.4	12.2	13.0	13.8	14.7	15.6	16.5	17.4	18.3	19.3	20.3	21.3
92	11.5	12.3	13.1	14.0	14.8	15.7	16.6	17.6	18.5	19.5	20.5	21.5
93	11.7	12.5	13.3	14.1	15.0	15.9	16.8	17.8	18.7	19.7	20.7	21.8
94	11.8	12.6	13.4	14.3	15.2	16.1	17.0	18.0	18.9	19.9	20.9	22.0
95	11.9	12.7	13.6	14.4	15.3	16.2	17.2	18.1	19.1	20.1	21.2	22.2
96	12.0	12.9	13.7	14.6	15.5	16.4	17.4	18.3	19.3	20.4	21.4	22.5
97	12.2	13.0	13.9	14.7	15.6	16.6	17.5	18.5	19.5	20.6	21.6	22.7
98	12.3	13.1	14.0	14.9	15.8	16.8	17.7	18.7	19.7	20.8	21.8	22.9
99	12.4	13.3	14.1	15.0	16.0	16.9	17.9	18.9	19.9	21.0	22.1	23.2
100	12.5	13.4	14.3	15.2	16.1	17.1	18.1	19.1	20.1	21.2	22.3	23.4
600	75.2	80.4	85.7	91.2	96.8	102.6	108.5	114.6	120.8	127.2	133.7	140.4
700	87.8	93.9	99.9	106.4	113.0	119.7	126.5	133.8	141.0	148.4	156.1	163.7
800	100.3	107.2	114.2	121.6	129.0	136.7	144.6	152.7	161.1	169.6	178.2	187.0
900	113.0	120.7	128.6	136.8	145.2	153.9	162.8	171.9	181.4	190.9	200.7	210.5
	1.14	1.15	1.17	1.18	1.19	1.21	1.22	1.24	1.25	1.27	1.29	1.31
	Factor											

To Change Dep. into Long. Diff. Multiply Tabular Number by Factor at Foot of Column and **add** Product to Dep.

TO CHANGE LONG. DIFF. INTO DEP., **SUBTRACT** TABULAR NUMBER FROM LONG. DIFF.

LONG. DIFF. OR DEP.	MIDDLE LATITUDE										
	41°	**42°**	**43°**	**44°**	**45°**	**46°**	**47°**	**48°**	**49°**	**50°**	**51°**
1	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4
2	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7
3	0.7	0.8	0.8	0.8	0.9	0.9	1.0	1.0	1.0	1.1	1.1
4	1.0	1.0	1.1	1.1	1.2	1.2	1.3	1.3	1.4	1.4	1.5
5	1.2	1.3	1.3	1.4	1.5	1.5	1.6	1.7	1.7	1.8	1.9
6	1.5	1.5	1.6	1.7	1.8	1.8	1.9	2.0	2.1	2.1	2.2
7	1.7	1.8	1.9	2.0	2.1	2.1	2.2	2.3	2.4	2.5	2.6
8	2.0	2.1	2.1	2.2	2.3	2.4	2.5	2.6	2.8	2.9	3.0
9	2.2	2.3	2.4	2.5	2.6	2.7	2.9	3.0	3.1	3.2	3.3
10	2.5	2.6	2.7	2.8	2.9	3.1	3.2	3.3	3.4	3.6	3.7
11	2.7	2.8	3.0	3.1	3.2	3.4	3.5	3.6	3.8	3.9	4.1
12	2.9	3.1	3.2	3.4	3.5	3.7	3.8	4.0	4.1	4.3	4.4
13	3.2	3.3	3.5	3.6	3.8	4.0	4.1	4.3	4.5	4.6	4.8
14	3.4	3.6	3.8	3.9	4.1	4.3	4.5	4.6	4.8	5.0	5.2
15	3.7	3.9	4.0	4.2	4.4	4.6	4.8	5.0	5.2	5.4	5.6
16	3.9	4.1	4.3	4.5	4.7	4.9	5.1	5.3	5.5	5.7	5.9
17	4.2	4.4	4.6	4.8	5.0	5.2	5.4	5.6	5.8	6.1	6.3
18	4.4	4.6	4.8	5.1	5.3	5.5	5.7	6.0	6.2	6.4	6.7
19	4.7	4.9	5.1	5.3	5.6	5.8	6.0	6.3	6.5	6.8	7.0
20	4.9	5.1	5.4	5.6	5.9	6.1	6.4	6.6	6.9	7.1	7.4
21	5.2	5.4	5.6	5.9	6.2	6.4	6.7	6.9	7.2	7.5	7.8
22	5.4	5.7	5.9	6.2	6.4	6.7	7.0	7.3	7.6	7.9	8.2
23	5.6	5.9	6.2	6.5	6.7	7.0	7.3	7.6	7.9	8.2	8.5
24	5.9	6.2	6.4	6.7	7.0	7.3	7.6	7.9	8.3	8.6	8.9
25	6.1	6.4	6.7	7.0	7.3	7.6	8.0	8.3	8.6	8.9	9.3
26	6.4	6.7	7.0	7.3	7.6	7.9	8.3	8.6	8.9	9.3	9.6
27	6.6	6.9	7.3	7.6	7.9	8.2	8.6	8.9	9.3	9.6	10.0
28	6.9	7.2	7.5	7.9	8.2	8.5	8.9	9.3	9.6	10.0	10.4
29	7.1	7.4	7.8	8.1	8.5	8.9	9.2	9.6	10.0	10.4	10.7
30	7.4	7.7	8.1	8.4	8.8	9.2	9.5	9.9	10.3	10.7	11.1
31	7.6	8.0	8.3	8.7	9.1	9.5	9.9	10.3	10.7	11.1	11.5
32	7.8	8.2	8.6	9.0	9.4	9.8	10.2	10.6	11.0	11.4	11.9
33	8.1	8.5	8.9	9.3	9.7	10.1	10.5	10.9	11.4	11.8	12.2
34	8.3	8.7	9.1	9.5	10.0	10.4	10.8	11.2	11.7	12.1	12.6
35	8.6	9.0	9.4	9.8	10.3	10.7	11.1	11.6	12.0	12.5	13.0
36	8.8	9.2	9.7	10.1	10.5	11.0	11.4	11.9	12.4	12.9	13.3
37	9.1	9.5	9.9	10.4	10.8	11.3	11.8	12.2	12.7	13.2	13.7
38	9.3	9.8	10.2	10.7	11.1	11.6	12.1	12.6	13.1	13.6	14.1
39	9.6	10.0	10.5	10.9	11.4	11.9	12.4	12.9	13.4	13.9	14.5
40	9.8	10.3	10.7	11.2	11.7	12.2	12.7	13.2	13.8	14.3	14.8
41	10.1	10.5	11.0	11.5	12.0	12.5	13.0	13.6	14.1	14.6	15.2
42	10.3	10.8	11.3	11.8	12.3	12.8	13.4	13.9	14.4	15.0	15.6
43	10.5	11.0	11.6	12.1	12.6	13.1	13.7	14.2	14.8	15.4	15.9
44	10.8	11.3	11.8	12.3	12.9	13.4	14.0	14.6	15.1	15.7	16.3
45	11.0	11.6	12.1	12.6	13.2	13.7	14.3	14.9	15.5	16.1	16.7
46	11.3	11.8	12.4	12.9	13.5	14.0	14.6	15.2	15.8	16.4	17.1
47	11.5	12.1	12.6	13.2	13.8	14.4	14.9	15.6	16.2	16.8	17.4
48	11.8	12.3	12.9	13.5	14.1	14.7	15.3	15.9	16.5	17.1	17.8
49	12.0	12.6	13.2	13.8	14.4	15.0	15.6	16.2	16.9	17.5	18.2
50	12.3	12.8	13.4	14.0	14.6	15.3	15.9	16.5	17.2	17.9	18.5
100	24.5	25.7	26.9	28.1	29.3	30.5	31.8	33.1	34.4	35.7	37.1
200	49.1	51.4	53.7	56.1	58.6	61.1	63.6	66.2	68.8	71.4	74.1
300	73.6	77.1	80.6	84.2	87.9	91.6	95.4	99.3	103.2	107.2	111.2
400	98.1	102.7	107.4	112.3	117.2	122.1	127.2	132.3	137.6	142.9	148.3
500	122.7	128.4	134.3	140.3	146.5	152.7	159.0	165.4	172.0	178.6	185.3
	1.33	1.35	1.37	1.39	1.41	1.44	1.47	1.50	1.52	1.56	1.59
	FACTOR										

TO CHANGE DEP. INTO LONG. DIFF., MULTIPLY TABULAR NUMBER BY FACTOR AT FOOT OF COLUMN, AND **ADD** PRODUCT TO DEP.

TO CHANGE LONG. DIFF. INTO DEP. **SUBTRACT** TABULAR NUMBER FROM LONG. DIFF.

Long. Diff. or Dep.	Middle Latitude										
	41°	42°	43°	44°	45°	46°	47°	48°	49°	50°	51°
51	12.5	13.1	13.7	14.3	14.9	15.6	16.2	16.9	17.5	18.2	18.9
52	12.8	13.4	14.0	14.6	15.2	15.9	16.5	17.2	17.9	18.6	19.3
53	13.0	13.6	14.2	14.9	15.5	16.2	16.9	17.5	18.2	18.9	19.6
54	13.2	13.9	14.5	15.2	15.8	16.5	17.2	17.9	18.6	19.3	20.0
55	13.5	14.1	14.8	15.4	16.1	16.8	17.5	18.2	18.9	19.6	20.4
56	13.7	14.4	15.0	15.7	16.4	17.1	17.8	18.5	19.3	20.0	20.8
57	14.0	14.6	15.3	16.0	16.7	17.4	18.1	18.9	19.6	20.4	21.1
58	14.2	14.9	15.6	16.3	17.0	17.7	18.4	19.2	19.9	20.7	21.5
59	14.5	15.2	15.9	16.6	17.3	18.0	18.8	19.5	20.3	21.1	21.9
60	14.7	15.4	16.1	16.8	17.6	18.3	19.1	19.9	20.6	21.4	22.2
61	15.0	15.7	16.4	17.1	17.9	18.6	19.4	20.2	21.0	21.8	22.6
62	15.2	15.9	16.7	17.4	18.2	18.9	19.7	20.5	21.3	22.1	23.0
63	15.5	16.2	16.9	17.7	18.5	19.2	20.0	20.8	21.7	22.5	23.4
64	15.7	16.4	17.2	18.0	18.7	19.5	20.4	21.2	22.0	22.9	23.7
65	15.9	16.7	17.5	18.2	19.0	19.8	20.7	21.5	22.4	23.2	24.1
66	16.2	17.0	17.7	18.5	19.3	20.2	21.0	21.8	22.7	23.6	24.5
67	16.4	17.2	18.0	18.8	19.6	20.5	21.3	22.2	23.0	23.9	24.8
68	16.7	17.5	18.3	19.1	19.9	20.8	21.6	22.5	23.4	24.3	25.2
69	16.9	17.7	18.5	19.4	20.2	21.1	21.9	22.8	23.7	24.6	25.6
70	17.2	18.0	18.8	19.6	20.5	21.4	22.3	23.2	24.1	25.0	25.9
71	17.4	18.2	19.1	19.9	20.8	21.7	22.6	23.5	24.4	25.4	26.3
72	17.7	18.5	19.3	20.2	21.1	22.0	22.9	23.8	24.8	25.7	26.7
73	17.9	18.8	19.6	20.5	21.4	22.3	23.2	24.2	25.1	26.1	27.1
74	18.2	19.0	19.9	20.8	21.7	22.6	23.5	24.5	25.5	26.4	27.4
75	18.4	19.3	20.1	21.0	22.0	22.9	23.9	24.8	25.8	26.8	27.8
76	18.6	19.5	20.4	21.3	22.3	23.2	24.2	25.1	26.1	27.1	28.2
77	18.9	19.8	20.7	21.6	22.6	23.5	24.5	25.5	26.5	27.5	28.5
78	19.1	20.0	21.0	21.9	22.8	23.8	24.8	25.8	26.8	27.9	28.9
79	19.4	20.3	21.2	22.2	23.1	24.1	25.1	26.1	27.2	28.2	29.3
80	19.6	20.5	21.5	22.5	23.4	24.4	25.4	26.5	27.5	28.6	29.7
81	19.9	20.8	21.8	22.7	23.7	24.7	25.8	26.8	27.9	28.9	30.0
82	20.1	21.1	22.0	23.0	24.0	25.0	26.1	27.1	28.2	29.3	30.4
83	20.4	21.3	22.3	23.3	24.3	25.3	26.4	27.5	28.5	29.6	30.8
84	20.6	21.6	22.6	23.6	24.6	25.6	26.7	27.8	28.9	30.0	31.1
85	20.8	21.8	22.8	23.9	24.9	26.0	27.0	28.1	29.2	30.4	31.5
86	21.1	22.1	23.1	24.1	25.2	26.3	27.3	28.5	29.6	30.7	31.9
87	21.3	22.3	23.4	24.4	25.5	26.6	27.7	28.8	29.9	31.1	32.2
88	21.6	22.6	23.6	24.7	25.8	26.9	28.0	29.1	30.3	31.4	32.6
89	21.8	22.9	23.9	25.0	26.1	27.2	28.3	29.4	30.6	31.8	33.0
90	22.1	23.1	24.2	25.3	26.4	27.5	28.6	29.8	31.0	32.1	33.4
91	22.3	23.4	24.4	25.5	26.7	27.8	28.9	30.1	31.3	32.5	33.7
92	22.6	23.6	24.7	25.8	26.9	28.1	29.3	30.4	31.6	32.9	34.1
93	22.8	23.9	25.0	26.1	27.2	28.4	29.6	30.8	32.0	33.2	34.5
94	23.1	24.1	25.3	26.4	27.5	28.7	29.9	31.1	32.3	33.6	34.8
95	23.3	24.4	25.5	26.7	27.8	29.0	30.2	31.4	32.7	33.9	35.2
96	23.5	24.7	25.8	26.9	28.1	29.3	30.5	31.8	33.0	34.3	35.6
97	23.8	24.9	26.1	27.2	28.4	29.6	30.8	32.1	33.4	34.6	36.0
98	24.0	25.2	26.3	27.5	28.7	29.9	31.2	32.4	33.7	35.0	36.3
99	24.3	25.4	26.6	27.8	29.0	30.2	31.5	32.8	34.1	35.4	36.7
100	24.5	25.7	26.9	28.1	29.3	30.5	31.8	33.1	34.4	35.7	37.1
600	147.2	154.1	161.2	168.4	175.7	183.2	190.8	198.5	206.4	214.3	222.4
700	171.7	179.8	188.1	196.5	205.0	213.7	222.6	231.6	240.8	250.0	259.4
800	196.1	205.4	214.9	224.6	234.3	244.2	254.4	264.7	275.2	285.8	296.5
900	220.8	231.2	241.8	252.7	263.7	274.8	286.2	297.8	309.7	321.5	333.7
Factor	1.33	1.35	1.37	1.39	1.41	1.44	1.47	1.50	1.52	1.56	1.59

TO CHANGE DEP. INTO LONG. DIFF. MULTIPLY TABULAR NUMBER BY FACTOR AT FOOT OF COLUMN AND **ADD** PRODUCT TO DEP.

To Change Long. Diff. into Dep., **subtract** Tabular Number from Long. Diff.

Long. Diff. or Dep.	Middle Latitude								
	52°	53°	54°	55°	56°	57°	58°	59°	60°
1	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5
2	0.8	0.8	0.8	0.9	0.9	0.9	0.9	1.0	1.0
3	1.2	1.2	1.2	1.3	1.3	1.4	1.4	1.5	1.5
4	1.5	1.6	1.6	1.7	1.8	1.8	1.9	1.9	2.0
5	1.9	2.0	2.1	2.1	2.2	2.3	2.4	2.4	2.5
6	2.3	2.4	2.5	2.6	2.6	2.7	2.8	2.9	3.0
7	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5
8	3.1	3.2	3.3	3.4	3.5	3.6	3.8	3.9	4.0
9	3.5	3.6	3.7	3.8	4.0	4.1	4.2	4.4	4.5
10	3.8	4.0	4.1	4.3	4.4	4.6	4.7	4.8	5.0
11	4.2	4.4	4.5	4.7	4.8	5.0	5.2	5.3	5.5
12	4.6	4.8	4.9	5.1	5.3	5.5	5.6	5.8	6.0
13	5.0	5.2	5.4	5.5	5.7	5.9	6.1	6.3	6.5
14	5.4	5.6	5.8	6.0	6.2	6.4	6.6	6.8	7.0
15	5.8	6.0	6.2	6.4	6.6	6.8	7.1	7.3	7.5
16	6.1	6.4	6.6	6.8	7.1	7.3	7.5	7.8	8.0
17	6.5	6.8	7.0	7.2	7.5	7.7	8.0	8.2	8.5
18	6.9	7.2	7.4	7.7	7.9	8.2	8.5	8.7	9.0
19	7.3	7.6	7.8	8.1	8.4	8.7	8.9	9.2	9.5
20	7.7	8.0	8.2	8.5	8.8	9.1	9.4	9.7	10.0
21	8.1	8.4	8.7	9.0	9.3	9.6	9.9	10.2	10.5
22	8.5	8.8	9.1	9.4	9.7	10.0	10.3	10.7	11.0
23	8.8	9.2	9.5	9.8	10.1	10.5	10.8	11.2	11.5
24	9.2	9.6	9.9	10.2	10.6	10.9	11.3	11.6	12.0
25	9.6	10.0	10.3	10.7	11.0	11.4	11.8	12.1	12.5
26	10.0	10.4	10.7	11.1	11.5	11.8	12.2	12.6	13.0
27	10.4	10.8	11.1	11.5	11.9	12.3	12.7	13.1	13.5
28	10.8	11.1	11.5	11.9	12.3	12.8	13.2	13.6	14.0
29	11.1	11.5	12.0	12.4	12.8	13.2	13.6	14.1	14.5
30	11.5	11.9	12.4	12.8	13.2	13.7	14.1	14.5	15.0
31	11.9	12.3	12.8	13.2	13.7	14.1	14.6	15.0	15.5
32	12.3	12.7	13.2	13.6	14.1	14.6	15.0	15.5	16.0
33	12.7	13.1	13.6	14.1	14.5	15.0	15.5	16.0	16.5
34	13.1	13.5	14.0	14.5	15.0	15.5	16.0	16.5	17.0
35	13.5	13.9	14.4	14.9	15.4	15.9	16.5	17.0	17.5
36	13.8	14.3	14.8	15.4	15.9	16.4	16.9	17.5	18.0
37	14.2	14.7	15.3	15.8	16.3	16.8	17.4	17.9	18.5
38	14.6	15.1	15.7	16.2	16.8	17.3	17.9	18.4	19.0
39	15.0	15.5	16.1	16.6	17.2	17.8	18.3	18.9	19.5
40	15.4	15.9	16.5	17.1	17.6	18.2	18.8	19.4	20.0
41	15.8	16.3	16.9	17.5	18.1	18.7	19.3	19.9	20.5
42	16.1	16.7	17.3	17.9	18.5	19.1	19.7	20.4	21.0
43	16.5	17.1	17.7	18.3	19.0	19.6	20.2	20.9	21.5
44	16.9	17.5	18.1	18.8	19.4	20.0	20.7	21.3	22.0
45	17.3	17.9	18.5	19.2	19.8	20.5	21.2	21.8	22.5
46	17.7	18.3	19.0	19.6	20.3	20.9	21.6	22.3	23.0
47	18.1	18.7	19.4	20.0	20.7	21.4	22.1	22.8	23.5
48	18.4	19.1	19.8	20.5	21.2	21.9	22.6	23.3	24.0
49	18.8	19.5	20.2	20.9	21.6	22.3	23.0	23.8	24.5
50	19.2	19.9	20.6	21.3	22.0	22.8	23.5	24.2	25.0
100	38.4	39.8	41.2	42.6	44.1	45.5	47.0	48.5	50.0
200	76.9	79.6	82.4	85.3	88.2	91.1	94.0	97.0	100.0
300	115.3	119.5	123.7	127.9	132.2	136.6	141.0	145.5	150.0
400	153.7	159.3	164.9	170.6	176.3	182.2	188.1	194.0	200.0
500	192.2	199.1	206.1	213.2	220.4	227.7	235.0	242.5	250.0
	1.62	1.66	1.70	1.74	1.79	1.84	1.89	1.94	2.00
	Factor								

To Change Dep. into Long. Diff., Multiply Tabular Number by Factor at Foot of Column and add Product to Dep.

To Change Long. Diff. into Dep. **SUBTRACT** Tabular Number from Long. Diff.

Long. Diff. or Dep.	Middle Latitude 52°	53°	54°	55°	56°	57°	58°	59°	60°
51	19.6	20.3	21.0	21.7	22.5	23.2	24.0	24.7	25.5
52	20.0	20.7	21.4	22.2	22.9	23.7	24.4	25.2	26.0
53	20.4	21.1	21.8	22.6	23.4	24.1	24.9	25.7	26.5
54	20.8	21.5	22.3	23.0	23.8	24.6	25.4	26.2	27.0
55	21.1	21.9	22.7	23.5	24.2	25.0	25.9	26.7	27.5
56	21.5	22.3	23.1	23.9	24.7	25.5	26.3	27.2	28.0
57	21.9	22.7	23.5	24.3	25.1	26.0	26.8	27.6	28.5
58	22.3	23.1	23.9	24.7	25.6	26.4	27.3	28.1	29.0
59	22.7	23.5	24.3	25.2	26.0	26.9	27.7	28.6	29.5
60	23.1	23.9	24.7	25.6	26.4	27.3	28.2	29.1	30.0
61	23.4	24.3	25.1	26.0	26.9	27.8	28.7	29.6	30.5
62	23.8	24.7	25.6	26.4	27.3	28.2	29.1	30.1	31.0
63	24.2	25.1	26.0	26.9	27.8	28.7	29.6	30.6	31.5
64	24.6	25.5	26.4	27.3	28.2	29.1	30.1	31.0	32.0
65	25.0	25.9	26.8	27.7	28.7	29.6	30.6	31.5	32.5
66	25.4	26.3	27.2	28.1	29.1	30.1	31.0	32.0	33.0
67	25.8	26.7	27.6	28.6	29.5	30.5	31.5	32.5	33.5
68	26.1	27.1	28.0	29.0	30.0	31.0	32.0	33.0	34.0
69	26.5	27.5	28.4	29.4	30.4	31.4	32.4	33.5	34.5
70	26.9	27.9	28.9	29.8	30.9	31.9	32.9	33.9	35.0
71	27.3	28.3	29.3	30.3	31.3	32.3	33.4	34.4	35.5
72	27.7	28.7	29.7	30.7	31.7	32.8	33.8	34.9	36.0
73	28.1	29.1	30.1	31.1	32.2	33.2	34.3	35.4	36.5
74	28.4	29.5	30.5	31.6	32.6	33.7	34.8	35.9	37.0
75	28.8	29.9	30.9	32.0	33.1	34.2	35.3	36.4	37.5
76	29.2	30.3	31.3	32.4	33.5	34.6	35.7	36.9	38.0
77	29.6	30.7	31.7	32.8	33.9	35.1	36.2	37.3	38.5
78	30.0	31.1	32.2	33.3	34.4	35.5	36.7	37.8	39.0
79	30.4	31.5	32.6	33.7	34.8	36.0	37.1	38.3	39.5
80	30.7	31.9	33.0	34.1	35.3	36.4	37.6	38.8	40.0
81	31.1	32.3	33.4	34.5	35.7	36.9	38.1	39.3	40.5
82	31.5	32.7	33.8	35.0	36.1	37.3	38.5	39.8	41.0
83	31.9	33.0	34.2	35.4	36.6	37.8	39.0	40.3	41.5
84	32.3	33.4	34.6	35.8	37.0	38.3	39.5	40.7	42.0
85	32.7	33.8	35.0	36.2	37.5	38.7	40.0	41.2	42.5
86	33.1	34.2	35.5	36.7	37.9	39.2	40.4	41.7	43.0
87	33.4	34.6	35.9	37.1	38.4	39.6	40.9	42.2	43.5
88	33.8	35.0	36.3	37.5	38.8	40.1	41.4	42.7	44.0
89	34.2	35.4	36.7	38.0	39.2	40.5	41.8	43.2	44.5
90	34.6	35.8	37.1	38.4	39.7	41.0	42.3	43.6	45.0
91	35.0	36.2	37.5	38.8	40.1	41.4	42.8	44.1	45.5
92	35.4	36.6	37.9	39.2	40.6	41.9	43.2	44.6	46.0
93	35.7	37.0	38.3	39.7	41.0	42.3	43.7	45.1	46.5
94	36.1	37.4	38.7	40.1	41.4	42.8	44.2	45.6	47.0
95	36.5	37.8	39.2	40.5	41.9	43.3	44.7	46.1	47.5
96	36.9	38.2	39.6	40.9	42.3	43.7	45.1	46.6	48.0
97	37.3	38.6	40.0	41.4	42.8	44.2	45.6	47.0	48.5
98	37.7	39.0	40.4	41.8	43.2	44.6	46.1	47.5	49.0
99	38.0	39.4	40.8	42.2	43.6	45.1	46.5	48.0	49.5
100	38.4	39.8	41.2	42.6	44.1	45.5	47.0	48.5	50.0
600	230.6	238.9	247.3	255.9	264.5	273.2	282.0	291.0	300.0
700	269.2	279.7	288.6	298.5	308.6	318.7	329.0	339.6	350.0
800	307.5	319.5	329.8	341.2	352.6	364.3	376.1	388.0	400.0
900	346.0	358.3	371.1	383.8	396.8	409.9	423.2	436.6	450.0
	1.63	1.66	1.70	1.74	1.79	1.84	1.89	1.94	2.00
	Factor								

To Change Dep. into Long. Diff. Multiply Tabular Number by Factor at Foot of Column and **ADD** Product to Dep.

	0	1	2	3	4	5	6	7	8	9
100	00 000	043	087	130	173	217	260	303	346	389
01	432	475	518	561	604	647	689	732	775	817
02	860	903	945	988	*030	*072	*115	*157	*199	*242
03	01 284	326	368	410	452	494	536	578	620	662
04	703	745	787	828	870	912	953	995	*036	*078
05	02 119	160	202	243	284	325	366	407	449	490
06	531	572	612	653	694	735	776	816	857	898
07	938	979	*019	*060	*100	*141	*181	*222	*262	*302
08	03 342	383	423	463	503	543	583	623	663	703
09	743	782	822	862	902	941	981	*021	*060	*100
110	04 139	179	218	258	297	336	376	415	454	493
11	532	571	610	650	689	727	766	805	844	883
12	922	961	999	*038	*077	*115	*154	*192	*231	*269
13	05 308	346	385	423	461	500	538	576	614	652
14	690	729	767	805	843	881	918	956	994	*032
15	06 070	108	145	183	221	258	296	333	371	408
16	446	483	521	558	595	633	670	707	744	781
17	819	856	893	930	967	*004	*041	*078	*115	*151
18	07 188	225	262	298	335	372	408	445	482	518
19	555	591	628	664	700	737	773	809	846	882
120	918	954	990	*027	*063	*099	*135	*171	*207	*243
21	08 279	314	350	386	422	458	493	529	565	600
22	636	672	707	743	778	814	849	884	920	955
23	991	*026	*061	*096	*132	*167	*202	*237	*272	*307
24	09 342	377	412	447	482	517	552	587	621	656
25	691	726	760	795	830	864	899	934	968	*003
26	10 037	072	106	140	175	209	243	278	312	346
27	380	415	449	483	517	551	585	619	653	687
28	721	755	789	823	857	890	924	958	992	*025
29	11 059	093	126	160	193	227	261	294	327	361
130	394	428	461	494	528	561	594	628	661	694
31	727	760	793	826	860	893	926	959	992	*024
32	12 057	090	123	156	189	222	254	287	320	352
33	385	418	450	483	516	548	581	613	646	678
34	710	743	775	808	840	872	905	937	969	*001
35	13 033	066	098	130	162	194	226	258	290	322
36	354	386	418	450	481	513	545	577	609	640
37	672	704	735	767	799	830	862	893	925	956
38	988	*019	*051	*082	*114	*145	*176	*208	*239	*270
39	14 301	333	364	395	426	457	489	520	551	582
140	613	644	675	706	737	768	799	829	860	891
41	922	953	983	*014	*045	*076	*106	*137	*168	*198
42	15 229	259	290	320	351	381	412	442	473	503
43	534	564	594	625	655	685	715	746	776	806
44	836	866	897	927	957	987	*017	*047	*077	*107
45	16 137	167	197	227	256	286	316	346	376	406
46	435	465	495	524	554	584	613	643	673	702
47	732	761	791	820	850	879	909	938	967	997
48	17 026	056	085	114	143	173	202	231	260	289
49	319	348	377	406	435	464	493	522	551	580
150	609	638	667	696	725	754	782	811	840	869
	0	1	2	3	4	5	6	7	8	9

Prop. Pts.

	44	43	42
1	4.4	4.3	4.2
2	8.8	8.6	8.4
3	13.2	12.9	12.6
4	17.6	17.2	16.8
5	22.0	21.5	21.0
6	26.4	25.8	25.2
7	30.8	30.1	29.4
8	35.2	34.4	33.6
9	39.6	38.7	37.8

	41	40	39
1	4.1	4.0	3.9
2	8.2	8.0	7.8
3	12.3	12.0	11.7
4	16.4	16.0	15.6
5	20.5	20.0	19.5
6	24.6	24.0	23.4
7	28.7	28.0	27.3
8	32.8	32.0	31.2
9	36.9	36.0	35.1

	38	37	36
1	3.8	3.7	3.6
2	7.6	7.4	7.2
3	11.4	11.1	10.8
4	15.2	14.8	14.4
5	19.0	18.5	18.0
6	22.8	22.2	21.6
7	26.6	25.9	25.2
8	30.4	29.6	28.8
9	34.2	33.3	32.4

	35	34	33
1	3.5	3.4	3.3
2	7.0	6.8	6.6
3	10.5	10.2	9.9
4	14.0	13.6	13.2
5	17.5	17.0	16.5
6	21.0	20.4	19.8
7	24.5	23.8	23.1
8	28.0	27.2	26.4
9	31.5	30.6	29.7

	32	31	30
1	3.2	3.1	3.0
2	6.4	6.2	6.0
3	9.6	9.3	9.0
4	12.8	12.4	12.0
5	16.0	15.5	15.0
6	19.2	18.6	18.0
7	22.4	21.7	21.0
8	25.6	24.8	24.0
9	28.8	27.9	27.0

Prop. Pts.

	0	1	2	3	4	5	6	7	8	9
150	17 609	638	667	696	725	754	782	811	840	869
51	898	926	955	984	*013	*041	*070	*099	*127	*156
52	18 184	213	241	270	298	327	355	384	412	441
53	469	498	526	554	583	611	639	667	696	724
54	752	780	808	837	865	893	921	949	977	*005
55	19 033	061	089	117	145	173	201	229	257	285
56	312	340	368	396	424	451	479	507	535	562
57	590	618	645	673	700	728	756	783	811	838
58	866	893	921	948	976	*003	*030	*058	*085	*112
59	20 140	167	194	222	249	276	303	330	358	385
160	412	439	466	493	520	548	575	602	629	656
61	683	710	737	763	790	817	844	871	898	925
62	952	978	*005	*032	*059	*085	*112	*139	*165	*192
63	21 219	245	272	299	325	352	378	405	431	458
64	484	511	537	564	590	617	643	669	696	722
65	748	775	801	827	854	880	906	932	958	985
66	22 011	037	063	089	115	141	167	194	220	246
67	272	298	324	350	376	401	427	453	479	505
68	531	557	583	608	634	660	686	712	737	763
69	789	814	840	866	891	917	943	968	994	*019
170	23 045	070	096	121	147	172	198	223	249	274
71	300	325	350	376	401	426	452	477	502	528
72	553	578	603	629	654	679	704	729	754	779
73	805	830	855	880	905	930	955	980	*005	*030
74	24 055	080	105	130	155	180	204	229	254	279
75	304	329	353	378	403	428	452	477	502	527
76	551	576	601	625	650	674	699	724	748	773
77	797	822	846	871	895	920	944	969	993	*018
78	25 042	066	091	115	139	164	188	212	237	261
79	285	310	334	358	382	406	431	455	479	503
180	527	551	575	600	624	648	672	696	720	744
81	768	792	816	840	864	888	912	935	959	983
82	26 007	031	055	079	102	126	150	174	198	221
83	245	269	293	316	340	364	387	411	435	458
84	482	505	529	553	576	600	623	647	670	694
85	717	741	764	788	811	834	858	881	905	928
86	951	975	998	*021	*045	*068	*091	*114	*138	*161
87	27 184	207	231	254	277	300	323	346	370	393
88	416	439	462	485	508	531	554	577	600	623
89	646	669	692	715	738	761	784	807	830	852
190	875	898	921	944	967	989	*012	*035	*058	*081
91	28 103	126	149	171	194	217	240	262	285	307
92	330	353	375	398	421	443	466	488	511	533
93	556	578	601	623	646	668	691	713	735	758
94	780	803	825	847	870	892	914	937	959	981
95	29 003	026	048	070	092	115	137	159	181	203
96	226	248	270	292	314	336	358	380	403	425
97	447	469	491	513	535	557	579	601	623	645
98	667	688	710	732	754	776	798	820	842	863
99	885	907	929	951	973	994	*016	*038	*060	*081
200	30 103	125	146	168	190	211	233	255	276	298
	0	1	2	3	4	5	6	7	8	9

Prop. Pts.

	29	28	27
1	2.9	2.8	2.7
2	5.8	5.6	5.4
3	8.7	8.4	8.1
4	11.6	11.2	10.8
5	14.5	14.0	13.5
6	17.4	16.8	16.2
7	20.3	19.6	18.9
8	23.2	22.4	21.6
9	26.1	25.2	24.3

	26	25	24
1	2.6	2.5	2.4
2	5.2	5.0	4.8
3	7.8	7.5	7.2
4	10.4	10.0	9.6
5	13.0	12.5	12.0
6	15.6	15.0	14.4
7	18.2	17.5	16.8
8	20.8	20.0	19.2
9	23.4	22.5	21.6

	23	22	21
1	2.3	2.2	2.1
2	4.6	4.4	4.2
3	6.9	6.6	6.3
4	9.2	8.8	8.4
5	11.5	11.0	10.5
6	13.8	13.2	12.6
7	16.1	15.4	14.7
8	18.4	17.6	16.8
9	20.7	19.8	18.9

Prop. Pts.

	0	1	2	3	4	5	6	7	8	9
200	30 103	125	146	168	190	211	233	255	276	298
01	320	341	363	384	406	428	449	471	492	514
02	535	557	578	600	621	643	664	685	707	728
03	750	771	792	814	835	856	878	899	920	942
04	963	984	*006	*027	*048	*069	*091	*112	*133	*154
05	31 175	197	218	239	260	281	302	323	345	366
06	387	408	429	450	471	492	513	534	555	576
07	597	618	639	660	681	702	723	744	765	785
08	806	827	848	869	890	911	931	952	973	994
09	32 015	035	056	077	098	118	139	160	181	201
210	222	243	263	284	305	325	346	366	387	408
11	428	449	469	490	510	531	552	572	593	613
12	634	654	675	695	715	736	756	777	797	818
13	838	858	879	899	919	940	960	980	*001	*021
14	33 041	062	082	102	122	143	163	183	203	224
15	244	264	284	304	325	345	365	385	405	425
16	445	465	486	506	526	546	566	586	606	626
17	646	666	686	706	726	746	766	786	806	826
18	846	866	885	905	925	945	965	985	*005	*025
19	34 044	064	084	104	124	143	163	183	203	223
220	242	262	282	301	321	341	361	380	400	420
21	439	459	479	498	518	537	557	577	596	616
22	635	655	674	694	713	733	753	772	792	811
23	830	850	869	889	908	928	947	967	986	*005
24	35 025	044	064	083	102	122	141	160	180	199
25	218	238	257	276	295	315	334	353	372	392
26	411	430	449	468	488	507	526	545	564	583
27	603	622	641	660	679	698	717	736	755	774
28	793	813	832	851	870	889	908	927	946	965
29	984	*003	*021	*040	*059	*078	*097	*116	*135	*154
230	36 173	192	211	229	248	267	286	305	324	342
31	361	380	399	418	436	455	474	493	511	530
32	549	568	586	605	624	642	661	680	698	717
33	736	754	773	791	810	829	847	866	884	903
34	922	940	959	977	996	*014	*033	*051	*070	*088
35	37 107	125	144	162	181	199	218	236	254	273
36	291	310	328	346	365	383	401	420	438	457
37	475	493	511	530	548	566	585	603	621	639
38	658	676	694	712	731	749	767	785	803	822
39	840	858	876	894	912	931	949	967	985	*003
240	38 021	039	057	075	093	112	130	148	166	184
41	202	220	238	256	274	292	310	328	346	364
42	382	399	417	435	453	471	489	507	525	543
43	561	578	596	614	632	650	668	686	703	721
44	739	757	775	792	810	828	846	863	881	899
45	917	934	952	970	987	*005	*023	*041	*058	*076
46	39 094	111	129	146	164	182	199	217	235	252
47	270	287	305	322	340	358	375	393	410	428
48	445	463	480	498	515	533	550	568	585	602
49	620	637	655	672	690	707	724	742	759	777
250	794	811	829	846	863	881	898	915	933	950
	0	1	2	3	4	5	6	7	8	9

Prop. Pts.

	22	21	20
1	2.2	2.1	2.0
2	4.4	4.2	4.0
3	6.6	6.3	6.0
4	8.8	8.4	8.0
5	11.0	10.5	10.0
6	13.2	12.6	12.0
7	15.4	14.7	14.0
8	17.6	16.8	16.0
9	19.8	18.9	18.0

	19	18	17
1	1.9	1.8	1.7
2	3.8	3.6	3.4
3	5.7	5.4	5.1
4	7.6	7.2	6.8
5	9.5	9.0	8.5
6	11.4	10.8	10.2
7	13.3	12.6	11.9
8	15.2	14.4	13.6
9	17.1	16.2	15.3

Prop. Pts.

	0	1	2	3	4	5	6	7	8	9
250	39 794	811	829	846	863	881	898	915	933	950
51	967	985	*002	*019	*037	*054	*071	*088	*106	*123
52	40 140	157	175	192	209	226	243	261	278	295
53	312	329	346	364	381	398	415	432	449	466
54	483	500	518	535	552	569	586	603	620	637
55	654	671	688	705	722	739	756	773	790	807
56	824	841	858	875	892	909	926	943	960	976
57	993	*010	*027	*044	*061	*078	*095	*111	*128	*145
58	41 162	179	196	212	229	246	263	280	296	313
59	330	347	363	380	397	414	430	447	464	481
260	497	514	531	547	564	581	597	614	631	647
61	664	681	697	714	731	747	764	780	797	814
62	830	847	863	880	896	913	929	946	963	979
63	996	*012	*029	*045	*062	*078	*095	*111	*127	*144
64	42 160	177	193	210	226	243	259	275	292	308
65	325	341	357	374	390	406	423	439	455	472
66	488	504	521	537	553	570	586	602	619	635
67	651	667	684	700	716	732	749	765	781	797
68	813	830	846	862	878	894	911	927	943	959
69	975	991	*008	*024	*040	*056	*072	*088	*104	*120
270	43 136	152	169	185	201	217	233	249	265	281
71	297	313	329	345	361	377	393	409	425	441
72	457	473	489	505	521	537	553	569	584	600
73	616	632	648	664	680	696	712	727	743	759
74	775	791	807	823	838	854	870	886	902	917
75	933	949	965	981	996	*012	*028	*044	*059	*075
76	44 091	107	122	138	154	170	185	201	217	232
77	248	264	279	295	311	326	342	358	373	389
78	404	420	436	451	467	483	498	514	529	545
79	560	576	592	607	623	638	654	669	685	700
280	716	731	747	762	778	793	809	824	840	855
81	871	886	902	917	932	948	963	979	994	*010
82	45 025	040	056	071	086	102	117	133	148	163
83	179	194	209	225	240	255	271	286	301	317
84	332	347	362	378	393	408	423	439	454	469
85	484	500	515	530	545	561	576	591	606	621
86	637	652	667	682	697	712	728	743	758	773
87	788	803	818	834	849	864	879	894	909	924
88	939	954	969	984	*000	*015	*030	*045	*060	*075
89	46 090	105	120	135	150	165	180	195	210	225
290	240	255	270	285	300	315	330	345	359	374
91	389	404	419	434	449	464	479	494	509	523
92	538	553	568	583	598	613	627	642	657	672
93	687	702	716	731	746	761	776	790	805	820
94	835	850	864	879	894	909	923	938	953	967
95	982	997	*012	*026	*041	*056	*070	*085	*100	*114
96	47 129	144	159	173	188	202	217	232	246	261
97	276	290	305	319	334	349	363	378	392	407
98	422	436	451	465	480	494	509	524	538	553
99	567	582	596	611	625	640	654	669	683	698
300	712	727	741	756	770	784	799	813	828	842
	0	1	2	3	4	5	6	7	8	9

Prop. Pts.

	18	17	16
1	1.8	1.7	1.6
2	3.6	3.4	3.2
3	5.4	5.1	4.8
4	7.2	6.8	6.4
5	9.0	8.5	8.0
6	10.8	10.2	9.6
7	12.6	11.9	11.2
8	14.4	13.6	12.8
9	16.2	15.3	14.4

	15	14
1	1.5	1.4
2	3.0	2.8
3	4.5	4.2
4	6.0	5.6
5	7.5	7.0
6	9.0	8.4
7	10.5	9.8
8	12.0	11.2
9	13.5	12.6

Prop. Pts.

	0	1	2	3	4	5	6	7	8	9
300	47 712	727	741	756	770	784	799	813	828	842
01	857	871	885	900	914	929	943	958	972	986
02	48 001	015	029	044	058	073	087	101	116	130
03	144	159	173	187	202	216	230	244	259	273
04	287	302	316	330	344	359	373	387	401	416
05	430	444	458	473	487	501	515	530	544	558
06	572	586	601	615	629	643	657	671	686	700
07	714	728	742	756	770	785	799	813	827	841
08	855	869	883	897	911	926	940	954	968	982
09	996	*010	*024	*038	*052	*066	*080	*094	*108	*122
310	49 136	150	164	178	192	206	220	234	248	262
11	276	290	304	318	332	346	360	374	388	402
12	415	429	443	457	471	485	499	513	527	541
13	554	568	582	596	610	624	638	651	665	679
14	693	707	721	734	748	762	776	790	803	817
15	831	845	859	872	886	900	914	927	941	955
16	969	982	996	*010	*024	*037	*051	*065	*079	*092
17	50 106	120	133	147	161	174	188	202	215	229
18	243	256	270	284	297	311	325	338	352	365
19	379	393	406	420	433	447	461	474	488	501
320	515	529	542	556	569	583	596	610	623	637
21	651	664	678	691	705	718	732	745	759	772
22	786	799	813	826	840	853	866	880	893	907
23	920	934	947	961	974	987	*001	*014	*028	*041
24	51 055	068	081	095	108	121	135	148	162	175
25	188	202	215	228	242	255	268	282	295	308
26	322	335	348	362	375	388	402	415	428	441
27	455	468	481	495	508	521	534	548	561	574
28	587	601	614	627	640	654	667	680	693	706
29	720	733	746	759	772	786	799	812	825	838
330	851	865	878	891	904	917	930	943	957	970
31	983	996	*009	*022	*035	*048	*061	*075	*088	*101
32	52 114	127	140	153	166	179	192	205	218	231
33	244	257	270	284	297	310	323	336	349	362
34	375	388	401	414	427	440	453	466	479	492
35	504	517	530	543	556	569	582	595	608	621
36	634	647	660	673	686	699	711	724	737	750
37	763	776	789	802	815	827	840	853	866	879
38	892	905	917	930	943	956	969	982	994	*007
39	53 020	033	046	058	071	084	097	110	122	135
340	148	161	173	186	199	212	224	237	250	263
41	275	288	301	314	326	339	352	364	377	390
42	403	415	428	441	453	466	479	491	504	517
43	529	542	555	567	580	593	605	618	631	643
44	656	668	681	694	706	719	732	744	757	769
45	782	794	807	820	832	845	857	870	882	895
46	908	920	933	945	958	970	983	995	*008	*020
47	54 033	045	058	070	083	095	108	120	133	145
48	158	170	183	195	208	220	233	245	258	270
49	283	295	307	320	332	345	357	370	382	394
350	407	419	432	444	456	469	481	494	506	518
	0	1	2	3	4	5	6	7	8	9

Prop. Pts.

	15	14
1	1.5	1.4
2	3.0	2.8
3	4.5	4.2
4	6.0	5.6
5	7.5	7.0
6	9.0	8.4
7	10.5	9.8
8	12.0	11.2
9	13.5	12.6

	13	12
1	1.3	1.2
2	2.6	2.4
3	3.9	3.6
4	5.2	4.8
5	6.5	6.0
6	7.8	7.2
7	9.1	8.4
8	10.4	9.6
9	11.7	10.8

Prop. Pts.

	0	1	2	3	4	5	6	7	8	9
350	54 407	419	432	444	456	469	481	494	506	518
51	531	543	555	568	580	593	605	617	630	642
52	654	667	679	691	704	716	728	741	753	765
53	777	790	802	814	827	839	851	864	876	888
54	900	913	925	937	949	962	974	986	998	*011
55	55 023	035	047	060	072	084	096	108	121	133
56	145	157	169	182	194	206	218	230	242	255
57	267	279	291	303	315	328	340	352	364	376
58	388	400	413	425	437	449	461	473	485	497
59	509	522	534	546	558	570	582	594	606	618
360	630	642	654	666	678	691	703	715	727	739
61	751	763	775	787	799	811	823	835	847	859
62	871	883	895	907	919	931	943	955	967	979
63	991	*003	*015	*027	*038	*050	*062	*074	*086	*098
64	56 110	122	134	146	158	170	182	194	205	217
65	229	241	253	265	277	289	301	312	324	336
66	348	360	372	384	396	407	419	431	443	455
67	467	478	490	502	514	526	538	549	561	573
68	585	597	608	620	632	644	656	667	679	691
69	703	714	726	738	750	761	773	785	797	808
370	820	832	844	855	867	879	891	902	914	926
71	937	949	961	972	984	996	*008	*019	*031	*043
72	57 054	066	078	089	101	113	124	136	148	159
73	171	183	194	206	217	229	241	252	264	276
74	287	299	310	322	334	345	357	368	380	392
75	403	415	426	438	449	461	473	484	496	507
76	519	530	542	553	565	576	588	600	611	623
77	634	646	657	669	680	692	703	715	726	738
78	749	761	772	784	795	807	818	830	841	852
79	864	875	887	898	910	921	933	944	955	967
380	978	990	*001	*013	*024	*035	*047	*058	*070	*081
81	58 092	104	115	127	138	149	161	172	184	195
82	206	218	229	240	252	263	274	286	297	309
83	320	331	343	354	365	377	388	399	410	422
84	433	444	456	467	478	490	501	512	524	535
85	546	557	569	580	591	602	614	625	636	647
86	659	670	681	692	704	715	726	737	749	760
87	771	782	794	805	816	827	838	850	861	872
88	883	894	906	917	928	939	950	961	973	984
89	995	*006	*017	*028	*040	*051	*062	*073	*084	*095
390	59 106	118	129	140	151	162	173	184	195	207
91	218	229	240	251	262	273	284	295	306	318
92	329	340	351	362	373	384	395	406	417	428
93	439	450	461	472	483	494	506	517	528	539
94	550	561	572	583	594	605	616	627	638	649
95	660	671	682	693	704	715	726	737	748	759
96	770	780	791	802	813	824	835	846	857	868
97	879	890	901	912	923	934	945	956	966	977
98	988	999	*010	*021	*032	*043	*054	*065	*076	*086
99	60 097	108	119	130	141	152	163	173	184	195
400	206	217	228	239	249	260	271	282	293	304
	0	1	2	3	4	5	6	7	8	9

Prop. Pts.

	13	12
1	1.3	1.2
2	2.6	2.4
3	3.9	3.6
4	5.2	4.8
5	6.5	6.0
6	7.8	7.2
7	9.1	8.4
8	10.4	9.6
9	11.7	10.8

	11	10
1	1.1	1.0
2	2.2	2.0
3	3.3	3.0
4	4.4	4.0
5	5.5	5.0
6	6.6	6.0
7	7.7	7.0
8	8.8	8.0
9	9.9	9.0

Prop. Pts.

	0	1	2	3	4	5	6	7	8	9
400	60 206	217	228	239	249	260	271	282	293	304
01	314	325	336	347	358	369	379	390	401	412
02	423	433	444	455	466	477	487	498	509	520
03	531	541	552	563	574	584	595	606	617	627
04	638	649	660	670	681	692	703	713	724	735
05	746	756	767	778	788	799	810	821	831	842
06	853	863	874	885	895	906	917	927	938	949
07	959	970	981	991	*002	*013	*023	*034	*045	*055
08	61 066	077	087	098	109	119	130	140	151	162
09	172	183	194	204	215	225	236	247	257	268
410	278	289	300	310	321	331	342	352	363	374
11	384	395	405	416	426	437	448	458	469	479
12	490	500	511	521	532	542	553	563	574	584
13	595	606	616	627	637	648	658	669	679	690
14	700	711	721	731	742	752	763	773	784	794
15	805	815	826	836	847	857	868	878	888	899
16	909	920	930	941	951	962	972	982	993	*003
17	62 014	024	034	045	055	066	076	086	097	107
18	118	128	138	149	159	170	180	190	201	211
19	221	232	242	252	263	273	284	294	304	315
420	325	335	346	356	366	377	387	397	408	418
21	428	439	449	459	469	480	490	500	511	521
22	531	542	552	562	572	583	593	603	613	624
23	634	644	655	665	675	685	696	706	716	726
24	737	747	757	767	778	788	798	808	818	829
25	839	849	859	870	880	890	900	910	921	931
26	941	951	961	972	982	992	*002	*012	*022	*033
27	63 043	053	063	073	083	094	104	114	124	134
28	144	155	165	175	185	195	205	215	225	236
29	246	256	266	276	286	296	306	317	327	337
430	347	357	367	377	387	397	407	417	428	438
31	448	458	468	478	488	498	508	518	528	538
32	548	558	568	579	589	599	609	619	629	639
33	649	659	669	679	689	699	709	719	729	739
34	749	759	769	779	789	799	809	819	829	839
35	849	859	869	879	889	899	909	919	929	939
36	949	959	969	979	988	998	*008	*018	*028	*038
37	64 048	058	068	078	088	098	108	118	128	137
38	147	157	167	177	187	197	207	217	227	237
39	246	256	266	276	286	296	306	316	326	335
440	345	355	365	375	385	395	404	414	424	434
41	444	454	464	473	483	493	503	513	523	532
42	542	552	562	572	582	591	601	611	621	631
43	640	650	660	670	680	689	699	709	719	729
44	738	748	758	768	777	787	797	807	816	826
45	836	846	856	865	875	885	895	904	914	924
46	933	943	953	963	972	982	992	*002	*011	*021
47	65 031	040	050	060	070	079	089	099	108	118
48	128	137	147	157	167	176	186	196	205	215
49	225	234	244	254	263	273	283	292	302	312
450	321	331	341	350	360	369	379	389	398	408
	0	1	2	3	4	5	6	7	8	9

Prop. Pts.

	11	10	9
1	1.1	1.0	0.9
2	2.2	2.0	1.8
3	3.3	3.0	2.7
4	4.4	4.0	3.6
5	5.5	5.0	4.5
6	6.6	6.0	5.4
7	7.7	7.0	6.3
8	8.8	8.0	7.2
9	9.9	9.0	8.1

Prop. Pts.

	0	1	2	3	4	5	6	7	8	9	Prop. Pts.
450	65 321	331	341	350	360	369	379	389	398	408	
51	418	427	437	447	456	466	475	485	495	504	
52	514	523	533	543	552	562	571	581	591	600	
53	610	619	629	639	648	658	667	677	686	696	
54	706	715	725	734	744	753	763	772	782	792	
55	801	811	820	830	839	849	858	868	877	887	
56	896	906	916	925	935	944	954	963	973	982	
57	992	*001	*011	*020	*030	*039	*049	*058	*068	*077	
58	66 087	096	106	115	124	134	143	153	162	172	
59	181	191	200	210	219	229	238	247	257	266	
460	276	285	295	304	314	323	332	342	351	361	
61	370	380	389	398	408	417	427	436	445	455	
62	464	474	483	492	502	511	521	530	539	549	
63	558	567	577	586	596	605	614	624	633	642	
64	652	661	671	680	689	699	708	717	727	736	
65	745	755	764	773	783	792	801	811	820	829	
66	839	848	857	867	876	885	894	904	913	922	
67	932	941	950	960	969	978	987	997	*006	*015	
68	67 025	034	043	052	062	071	080	089	099	108	
69	117	127	136	145	154	164	173	182	191	201	
470	210	219	228	237	247	256	265	274	284	293	
71	302	311	321	330	339	348	357	367	376	385	
72	394	403	413	422	431	440	449	459	468	477	
73	486	495	504	514	523	532	541	550	560	569	
74	578	587	596	605	614	624	633	642	651	660	
75	669	679	688	697	706	715	724	733	742	752	
76	761	770	779	788	797	806	815	825	834	843	
77	852	861	870	879	888	897	906	916	925	934	
78	943	952	961	970	979	988	997	*006	*015	*024	
79	68 034	043	052	061	070	079	088	097	106	115	
480	124	133	142	151	160	169	178	187	196	205	
81	215	224	233	242	251	260	269	278	287	296	
82	305	314	323	332	341	350	359	368	377	386	
83	395	404	413	422	431	440	449	458	467	476	
84	485	494	502	511	520	529	538	547	556	565	
85	574	583	592	601	610	619	628	637	646	655	
86	664	673	681	690	699	708	717	726	735	744	
87	753	762	771	780	789	797	806	815	824	833	
88	842	851	860	869	878	886	895	904	913	922	
89	931	940	949	958	966	975	984	993	*002	*011	
490	69 020	028	037	046	055	064	073	082	090	099	
91	108	117	126	135	144	152	161	170	179	188	
92	197	205	214	223	232	241	249	258	267	276	
93	285	294	302	311	320	329	338	346	355	364	
94	373	381	390	399	408	417	425	434	443	452	
95	461	469	478	487	496	504	513	522	531	539	
96	548	557	566	574	583	592	601	609	618	627	
97	636	644	653	662	671	679	688	697	705	714	
98	723	732	740	749	758	767	775	784	793	801	
99	810	819	827	836	845	854	862	871	880	888	
500	897	906	914	923	932	940	949	958	966	975	
	0	1	2	3	4	5	6	7	8	9	Prop. Pts.

Prop. Pts.

	10	9	8
1	1.0	0.9	0.8
2	2.0	1.8	1.6
3	3.0	2.7	2.4
4	4.0	3.6	3.2
5	5.0	4.5	4.0
6	6.0	5.4	4.8
7	7.0	6.3	5.6
8	8.0	7.2	6.4
9	9.0	8.1	7.2

	0	1	2	3	4	5	6	7	8	9
500	69 897	906	914	923	932	940	949	958	966	975
01	984	992	*001	*010	*018	*027	*036	*044	*053	*062
02	70 070	079	088	096	105	114	122	131	140	148
03	157	165	174	183	191	200	209	217	226	234
04	243	252	260	269	278	286	295	303	312	321
05	329	338	346	355	364	372	381	389	398	406
06	415	424	432	441	449	458	467	475	484	492
07	501	509	518	526	535	544	552	561	569	578
08	586	595	603	612	621	629	638	646	655	663
09	672	680	689	697	706	714	723	731	740	749
510	757	766	774	783	791	800	808	817	825	834
11	842	851	859	868	876	885	893	902	910	919
12	927	935	944	952	961	969	978	986	995	*003
13	71 012	020	029	037	046	054	063	071	079	088
14	096	105	113	122	130	139	147	155	164	172
15	181	189	198	206	214	223	231	240	248	257
16	265	273	282	290	299	307	315	324	332	341
17	349	357	366	374	383	391	399	408	416	425
18	433	441	450	458	466	475	483	492	500	508
19	517	525	533	542	550	559	567	575	584	592
520	600	609	617	625	634	642	650	659	667	675
21	684	692	700	709	717	725	734	742	750	759
22	767	775	784	792	800	809	817	825	834	842
23	850	858	867	875	883	892	900	908	917	925
24	933	941	950	958	966	975	983	991	999	*008
25	72 016	024	032	041	049	057	066	074	082	090
26	099	107	115	123	132	140	148	156	165	173
27	181	189	198	206	214	222	230	239	247	255
28	263	272	280	288	296	304	313	321	329	337
29	346	354	362	370	378	387	395	403	411	419
530	428	436	444	452	460	469	477	485	493	501
31	509	518	526	534	542	550	558	567	575	583
32	591	599	607	616	624	632	640	648	656	665
33	673	681	689	697	705	713	722	730	738	746
34	754	762	770	779	787	795	803	811	819	827
35	835	843	852	860	868	876	884	892	900	908
36	916	925	933	941	949	957	965	973	981	989
37	997	*006	*014	*022	*030	*038	*046	*054	*062	*070
38	73 078	086	094	102	111	119	127	135	143	151
39	159	167	175	183	191	199	207	215	223	231
540	239	247	255	263	272	280	288	296	304	312
41	320	328	336	344	352	360	368	376	384	392
42	400	408	416	424	432	440	448	456	464	472
43	480	488	496	504	512	520	528	536	544	552
44	560	568	576	584	592	600	608	616	624	632
45	640	648	656	664	672	679	687	695	703	711
46	719	727	735	743	751	759	767	775	783	791
47	799	807	815	823	830	838	846	854	862	870
48	878	886	894	902	910	918	926	933	941	949
49	957	965	973	981	989	997	*005	*013	*020	*028
550	74 036	044	052	060	068	076	084	092	099	107
	0	1	2	3	4	5	6	7	8	9

Prop. Pts.

	9	8	7
1	0.9	0.8	0.7
2	1.8	1.6	1.4
3	2.7	2.4	2.1
4	3.6	3.2	2.8
5	4.5	4.0	3.5
6	5.4	4.8	4.2
7	6.3	5.6	4.9
8	7.2	6.4	5.6
9	8.1	7.2	6.3

Prop. Pts.

	0	1	2	3	4	5	6	7	8	9
550	74 036	044	052	060	068	076	084	092	099	107
51	115	123	131	139	147	155	162	170	178	186
52	194	202	210	218	225	233	241	249	257	265
53	273	280	288	296	304	312	320	327	335	343
54	351	359	367	374	382	390	398	406	414	421
55	429	437	445	453	461	468	476	484	492	500
56	507	515	523	531	539	547	554	562	570	578
57	586	593	601	609	617	624	632	640	648	656
58	663	671	679	687	695	702	710	718	726	733
59	741	749	757	764	772	780	788	796	803	811
560	819	827	834	842	850	858	865	873	881	889
61	896	904	912	920	927	935	943	950	958	966
62	974	981	989	997	*005	*012	*020	*028	*035	*043
63	75 051	059	066	074	082	089	097	105	113	120
64	128	136	143	151	159	166	174	182	189	197
65	205	213	220	228	236	243	251	259	266	274
66	282	289	297	305	312	320	328	335	343	351
67	358	366	374	381	389	397	404	412	420	427
68	435	442	450	458	465	473	481	488	496	504
69	511	519	526	534	542	549	557	565	572	580
570	587	595	603	610	618	626	633	641	648	656
71	664	671	679	686	694	702	709	717	724	732
72	740	747	755	762	770	778	785	793	800	808
73	815	823	831	838	846	853	861	868	876	884
74	891	899	906	914	921	929	937	944	952	959
75	967	974	982	989	997	*005	*012	*020	*027	*035
76	76 042	050	057	065	072	080	087	095	103	110
77	118	125	133	140	148	155	163	170	178	185
78	193	200	208	215	223	230	238	245	253	260
79	268	275	283	290	298	305	313	320	328	335
580	343	350	358	365	373	380	388	395	403	410
81	418	425	433	440	448	455	462	470	477	485
82	492	500	507	515	522	530	537	545	552	559
83	567	574	582	589	597	604	612	619	626	634
84	641	649	656	664	671	678	686	693	701	708
85	716	723	730	738	745	753	760	768	775	782
86	790	797	805	812	819	827	834	842	849	856
87	864	871	879	886	893	901	908	916	923	930
88	938	945	953	960	967	975	982	989	997	*004
89	77 012	019	026	034	041	048	056	063	070	078
590	085	093	100	107	115	122	129	137	144	151
91	159	166	173	181	188	195	203	210	217	225
92	232	240	247	254	262	269	276	283	291	298
93	305	313	320	327	335	342	349	357	364	371
94	379	386	393	401	408	415	422	430	437	444
95	452	459	466	474	481	488	495	503	510	517
96	525	532	539	546	554	561	568	576	583	590
97	597	605	612	619	627	634	641	648	656	663
98	670	677	685	692	699	706	714	721	728	735
99	743	750	757	764	772	779	786	793	801	808
600	815	822	830	837	844	851	859	866	873	880

Prop. Pts.

	8	7
1	0.8	0.7
2	1.6	1.4
3	2.4	2.1
4	3.2	2.8
5	4.0	3.5
6	4.8	4.2
7	5.6	4.9
8	6.4	5.6
9	7.2	6.3

	0	1	2	3	4	5	6	7	8	9
600	77 815	822	830	837	844	851	859	866	873	880
01	887	895	902	909	916	924	931	938	945	952
02	960	967	974	981	988	996	*003	*010	*017	*025
03	78 032	039	046	053	061	068	075	082	089	097
04	104	111	118	125	132	140	147	154	161	168
05	176	183	190	197	204	211	219	226	233	240
06	247	254	262	269	276	283	290	297	305	312
07	319	326	333	340	347	355	362	369	376	383
08	390	398	405	412	419	426	433	440	447	455
09	462	469	476	483	490	497	504	512	519	526
610	533	540	547	554	561	569	576	583	590	597
11	604	611	618	625	633	640	647	654	661	668
12	675	682	689	696	704	711	718	725	732	739
13	746	753	760	767	774	781	789	796	803	810
14	817	824	831	838	845	852	859	866	873	880
15	888	895	902	909	916	923	930	937	944	951
16	958	965	972	979	986	993	*000	*007	*014	*021
17	79 029	036	043	050	057	064	071	078	085	092
18	099	106	113	120	127	134	141	148	155	162
19	169	176	183	190	197	204	211	218	225	232
620	239	246	253	260	267	274	281	288	295	302
21	309	316	323	330	337	344	351	358	365	372
22	379	386	393	400	407	414	421	428	435	442
23	449	456	463	470	477	484	491	498	505	511
24	518	525	532	539	546	553	560	567	574	581
25	588	595	602	609	616	623	630	637	644	650
26	657	664	671	678	685	692	699	706	713	720
27	727	734	741	748	754	761	768	775	782	789
28	796	803	810	817	824	831	837	844	851	858
29	865	872	879	886	893	900	906	913	920	927
630	934	941	948	955	962	969	975	982	989	996
31	80 003	010	017	024	030	037	044	051	058	065
32	072	079	085	092	099	106	113	120	127	134
33	140	147	154	161	168	175	182	188	195	202
34	209	216	223	229	236	243	250	257	264	271
35	277	284	291	298	305	312	318	325	332	339
36	346	353	359	366	373	380	387	393	400	407
37	414	421	428	434	441	448	455	462	468	475
38	482	489	496	502	509	516	523	530	536	543
39	550	557	564	570	577	584	591	598	604	611
640	618	625	632	638	645	652	659	665	672	679
41	686	693	699	706	713	720	726	733	740	747
42	754	760	767	774	781	787	794	801	808	814
43	821	828	835	841	848	855	862	868	875	882
44	889	895	902	909	916	922	929	936	943	949
45	956	963	969	976	983	990	996	*003	*010	*017
46	81 023	030	037	043	050	057	064	070	077	084
47	090	097	104	111	117	124	131	137	144	151
48	158	164	171	178	184	191	198	204	211	218
49	224	231	238	245	251	258	265	271	278	285
650	291	298	305	311	318	325	331	338	345	351
	0	1	2	3	4	5	6	7	8	9

Prop. Pts.

	8	7	6
1	0.8	0.7	0.6
2	1.6	1.4	1.2
3	2.4	2.1	1.8
4	3.2	2.8	2.4
5	4.0	3.5	3.0
6	4.8	4.2	3.6
7	5.6	4.9	4.2
8	6.4	5.6	4.8
9	7.2	6.3	5.4

Prop. Pts.

	0	1	2	3	4	5	6	7	8	9
650	81 291	298	305	311	318	325	331	338	345	351
51	358	365	371	378	385	391	398	405	411	418
52	425	431	438	445	451	458	465	471	478	485
53	491	498	505	511	518	525	531	538	544	551
54	558	564	571	578	584	591	598	604	611	617
55	624	631	637	644	651	657	664	671	677	684
56	690	697	704	710	717	723	730	737	743	750
57	757	763	770	776	783	790	796	803	809	816
58	823	829	836	842	849	856	862	869	875	882
59	889	895	902	908	915	921	928	935	941	948
660	954	961	968	974	981	987	994	*000	*007	*014
61	82 020	027	033	040	046	053	060	066	073	079
62	086	092	099	105	112	119	125	132	138	145
63	151	158	164	171	178	184	191	197	204	210
64	217	223	230	236	243	249	256	263	269	276
65	282	289	295	302	308	315	321	328	334	341
66	347	354	360	367	373	380	387	393	400	406
67	413	419	426	432	439	445	452	458	465	471
68	478	484	491	497	504	510	517	523	530	536
69	543	549	556	562	569	575	582	588	595	601
670	607	614	620	627	633	640	646	653	659	666
71	672	679	685	692	698	705	711	718	724	730
72	737	743	750	756	763	769	776	782	789	795
73	802	808	814	821	827	834	840	847	853	860
74	866	872	879	885	892	898	905	911	918	924
75	930	937	943	950	956	963	969	975	982	988
76	995	*001	*008	*014	*020	*027	*033	*040	*046	*052
77	83 059	065	072	078	085	091	097	104	110	117
78	123	129	136	142	149	155	161	168	174	181
79	187	193	200	206	213	219	225	232	238	245
680	251	257	264	270	276	283	289	296	302	308
81	315	321	327	334	340	347	353	359	366	372
82	378	385	391	398	404	410	417	423	429	436
83	442	448	455	461	467	474	480	487	493	499
84	506	512	518	525	531	537	544	550	556	563
85	569	575	582	588	594	601	607	613	620	626
86	632	639	645	651	658	664	670	677	683	689
87	696	702	708	715	721	727	734	740	746	753
88	759	765	771	778	784	790	797	803	809	816
89	822	828	835	841	847	853	860	866	872	879
690	885	891	897	904	910	916	923	929	935	942
91	948	954	960	967	973	979	985	992	998	*004
92	84 011	017	023	029	036	042	048	055	061	067
93	073	080	086	092	098	105	111	117	123	130
94	136	142	148	155	161	167	173	180	186	192
95	198	205	211	217	223	230	236	242	248	255
96	261	267	273	280	286	292	298	305	311	317
97	323	330	336	342	348	354	361	367	373	379
98	386	392	398	404	410	417	423	429	435	442
99	448	454	460	466	473	479	485	491	497	504
700	510	516	522	528	535	541	547	553	559	566
	0	1	2	3	4	5	6	7	8	9

Prop. Pts.

	7	6
1	0.7	0.6
2	1.4	1.2
3	2.1	1.8
4	2.8	2.4
5	3.5	3.0
6	4.2	3.6
7	4.9	4.2
8	5.6	4.8
9	6.3	5.4

Prop. Pts.

	0	1	2	3	4	5	6	7	8	9
700	84 510	516	522	528	535	541	547	553	559	566
01	572	578	584	590	597	603	609	615	621	628
02	634	640	646	652	658	665	671	677	683	689
03	696	702	708	714	720	726	733	739	745	751
04	757	763	770	776	782	788	794	800	807	813
05	819	825	831	837	844	850	856	862	868	874
06	880	887	893	899	905	911	917	924	930	936
07	942	948	954	960	967	973	979	985	991	997
08	85 003	009	016	022	028	034	040	046	052	058
09	065	071	077	083	089	095	101	107	114	120
710	126	132	138	144	150	156	163	169	175	181
11	187	193	199	205	211	217	224	230	236	242
12	248	254	260	266	272	278	285	291	297	303
13	309	315	321	327	333	339	345	352	358	364
14	370	376	382	388	394	400	406	412	418	425
15	431	437	443	449	455	461	467	473	479	485
16	491	497	503	509	516	522	528	534	540	546
17	552	558	564	570	576	582	588	594	600	606
18	612	618	625	631	637	643	649	655	661	667
19	673	679	685	691	697	703	709	715	721	727
720	733	739	745	751	757	763	769	775	781	788
21	794	800	806	812	818	824	830	836	842	848
22	854	860	866	872	878	884	890	896	902	908
23	914	920	926	932	938	944	950	956	962	968
24	974	980	986	992	998	*004	*010	*016	*022	*028
25	86 034	040	046	052	058	064	070	076	082	088
26	094	100	106	112	118	124	130	136	141	147
27	153	159	165	171	177	183	189	195	201	207
28	213	219	225	231	237	243	249	255	261	267
29	273	279	285	291	297	303	308	314	320	326
730	332	338	344	350	356	362	368	374	380	386
31	392	398	404	410	415	421	427	433	439	445
32	451	457	463	469	475	481	487	493	499	504
33	510	516	522	528	534	540	546	552	558	564
34	570	576	581	587	593	599	605	611	617	623
35	629	635	641	646	652	658	664	670	676	682
36	688	694	700	705	711	717	723	729	735	741
37	747	753	759	764	770	776	782	788	794	800
38	806	812	817	823	829	835	841	847	853	859
39	864	870	876	882	888	894	900	906	911	917
740	923	929	935	941	947	953	958	964	970	976
41	982	988	994	999	*005	*011	*017	*023	*029	*035
42	87 040	046	052	058	064	070	075	081	087	093
43	099	105	111	116	122	128	134	140	146	151
44	157	163	169	175	181	186	192	198	204	210
45	216	221	227	233	239	245	251	256	262	268
46	274	280	286	291	297	303	309	315	320	326
47	332	338	344	349	355	361	367	373	379	384
48	390	396	402	408	413	419	425	431	437	442
49	448	454	460	466	471	477	483	489	495	500
750	506	512	518	523	529	535	541	547	552	558
	0	1	2	3	4	5	6	7	8	9

Prop. Pts.

	7	6	5
1	0.7	0.6	0.5
2	1.4	1.2	1.0
3	2.1	1.8	1.5
4	2.8	2.4	2.0
5	3.5	3.0	2.5
6	4.2	3.6	3.0
7	4.9	4.2	3.5
8	5.6	4.8	4.0
9	6.3	5.4	4.5

Prop. Pts.

	0	1	2	3	4	5	6	7	8	9
750	87 506	512	518	523	529	535	541	547	552	558
51	564	570	576	581	587	593	599	604	610	616
52	622	628	633	639	645	651	656	662	668	674
53	679	685	691	697	703	708	714	720	726	731
54	737	743	749	754	760	766	772	777	783	789
55	795	800	806	812	818	823	829	835	841	846
56	852	858	864	869	875	881	887	892	898	904
57	910	915	921	927	933	938	944	950	955	961
58	967	973	978	984	990	996	*001	*007	*013	*018
59	88 024	030	036	041	047	053	058	064	070	076
760	081	087	093	098	104	110	116	121	127	133
61	138	144	150	156	161	167	173	178	184	190
62	195	201	207	213	218	224	230	235	241	247
63	252	258	264	270	275	281	287	292	298	304
64	309	315	321	326	332	338	343	349	355	360
65	366	372	377	383	389	395	400	406	412	417
66	423	429	434	440	446	451	457	463	468	474
67	480	485	491	497	502	508	513	519	525	530
68	536	542	547	553	559	564	570	576	581	587
69	593	598	604	610	615	621	627	632	638	643
770	649	655	660	666	672	677	683	689	694	700
71	705	711	717	722	728	734	739	745	750	756
72	762	767	773	779	784	790	795	801	807	812
73	818	824	829	835	840	846	852	857	863	868
74	874	880	885	891	897	902	908	913	919	925
75	930	936	941	947	953	958	964	969	975	981
76	986	992	997	*003	*009	*014	*020	*025	*031	*037
77	89 042	048	053	059	064	070	076	081	087	092
78	098	104	109	115	120	126	131	137	143	148
79	154	159	165	170	176	182	187	193	198	204
780	209	215	221	226	232	237	243	248	254	260
81	265	271	276	282	287	293	298	304	310	315
82	321	326	332	337	343	348	354	360	365	371
83	376	382	387	393	398	404	409	415	421	426
84	432	437	443	448	454	459	465	470	476	481
85	487	492	498	504	509	515	520	526	531	537
86	542	548	553	559	564	570	575	581	586	592
87	597	603	609	614	620	625	631	636	642	647
88	653	658	664	669	675	680	686	691	697	702
89	708	713	719	724	730	735	741	746	752	757
790	763	768	774	779	785	790	796	801	807	812
91	818	823	829	834	840	845	851	856	862	867
92	873	878	883	889	894	900	905	911	916	922
93	927	933	938	944	949	955	960	966	971	977
94	982	988	993	998	*004	*009	*015	*020	*026	*031
95	90 037	042	048	053	059	064	069	075	080	086
96	091	097	102	108	113	119	124	129	135	140
97	146	151	157	162	168	173	179	184	189	195
98	200	206	211	217	222	227	233	238	244	249
99	255	260	266	271	276	282	287	293	298	304
800	309	314	320	325	331	336	342	347	352	358
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**

Prop. Pts.

	6	5
1	0.6	0.5
2	1.2	1.0
3	1.8	1.5
4	2.4	2.0
5	3.0	2.5
6	3.6	3.0
7	4.2	3.5
8	4.8	4.0
9	5.4	4.5

Prop. Pts.

	0	1	2	3	4	5	6	7	8	9
800	90 309	314	320	325	331	336	342	347	352	358
01	363	369	374	380	385	390	396	401	407	412
02	417	423	428	434	439	445	450	455	461	466
03	472	477	482	488	493	499	504	509	515	520
04	526	531	536	542	547	553	558	563	569	574
05	580	585	590	596	601	607	612	617	623	628
06	634	639	644	650	655	660	666	671	677	682
07	687	693	698	703	709	714	720	725	730	736
08	741	747	752	757	763	768	773	779	784	789
09	795	800	806	811	816	822	827	832	838	843
810	849	854	859	865	870	875	881	886	891	897
11	902	907	913	918	924	929	934	940	945	950
12	956	961	966	972	977	982	988	993	998	*004
13	91 009	014	020	025	030	036	041	046	052	057
14	062	068	073	078	084	089	094	100	105	110
15	116	121	126	132	137	142	148	153	158	164
16	169	174	180	185	190	196	201	206	212	217
17	222	228	233	238	243	249	254	259	265	270
18	275	281	286	291	297	302	307	312	318	323
19	328	334	339	344	350	355	360	365	371	376
820	381	387	392	397	403	408	413	418	424	429
21	434	440	445	450	455	461	466	471	477	482
22	487	492	498	503	508	514	519	524	529	535
23	540	545	551	556	561	566	572	577	582	587
24	593	598	603	609	614	619	624	630	635	640
25	645	651	656	661	666	672	677	682	687	693
26	698	703	709	714	719	724	730	735	740	745
27	751	756	761	766	772	777	782	787	793	798
28	803	808	814	819	824	829	834	840	845	850
29	855	861	866	871	876	882	887	892	897	903
830	908	913	918	924	929	934	939	944	950	955
31	960	965	971	976	981	986	991	997	*002	*007
32	92 012	018	023	028	033	038	044	049	054	059
33	065	070	075	080	085	091	096	101	106	111
34	117	122	127	132	137	143	148	153	158	163
35	169	174	179	184	189	195	200	205	210	215
36	221	226	231	236	241	247	252	257	262	267
37	273	278	283	288	293	298	304	309	314	319
38	324	330	335	340	345	350	355	361	366	371
39	376	381	387	392	397	402	407	412	418	423
840	428	433	438	443	449	454	459	464	469	474
41	480	485	490	495	500	505	511	516	521	526
42	531	536	542	547	552	557	562	567	572	578
43	583	588	593	598	603	609	614	619	624	629
44	634	639	645	650	655	660	665	670	675	681
45	686	691	696	701	706	711	716	722	727	732
46	737	742	747	752	758	763	768	773	778	783
47	788	793	799	804	809	814	819	824	829	834
48	840	845	850	855	860	865	870	875	881	886
49	891	896	901	906	911	916	921	927	932	937
850	942	947	952	957	962	967	973	978	983	988
	0	1	2	3	4	5	6	7	8	9

Prop. Pts.

	6	5
1	0.6	0.5
2	1.2	1.0
3	1.8	1.5
4	2.4	2.0
5	3.0	2.5
6	3.6	3.0
7	4.2	3.5
8	4.8	4.0
9	5.4	4.5

Prop. Pts.

	0	1	2	3	4	5	6	7	8	9
850	92 942	947	952	957	962	967	973	978	983	988
51	993	998	*003	*008	*013	*018	*024	*029	*034	*039
52	93 044	049	054	059	064	069	075	080	085	090
53	095	100	105	110	115	120	125	131	136	141
54	146	151	156	161	166	171	176	181	186	192
55	197	202	207	212	217	222	227	232	237	242
56	247	252	258	263	268	273	278	283	288	293
57	298	303	308	313	318	323	328	334	339	344
58	349	354	359	364	369	374	379	384	389	394
59	399	404	409	414	420	425	430	435	440	445
860	450	455	460	465	470	475	480	485	490	495
61	500	505	510	515	520	526	531	536	541	546
62	551	556	561	566	571	576	581	586	591	596
63	601	606	611	616	621	626	631	636	641	646
64	651	656	661	666	671	676	682	687	692	697
65	702	707	712	717	722	727	732	737	742	747
66	752	757	762	767	772	777	782	787	792	797
67	802	807	812	817	822	827	832	837	842	847
68	852	857	862	867	872	877	882	887	892	897
69	902	907	912	917	922	927	932	937	942	947
870	952	957	962	967	972	977	982	987	992	997
71	94 002	007	012	017	022	027	032	037	042	047
72	052	057	062	067	072	077	082	086	091	096
73	101	106	111	116	121	126	131	136	141	146
74	151	156	161	166	171	176	181	186	191	196
75	201	206	211	216	221	226	231	236	240	245
76	250	255	260	265	270	275	280	285	290	295
77	300	305	310	315	320	325	330	335	340	345
78	349	354	359	364	369	374	379	384	389	394
79	399	404	409	414	419	424	429	433	438	443
880	448	453	458	463	468	473	478	483	488	493
81	498	503	507	512	517	522	527	532	537	542
82	547	552	557	562	567	571	576	581	586	591
83	596	601	606	611	616	621	626	630	635	640
84	645	650	655	660	665	670	675	680	685	689
85	694	699	704	709	714	719	724	729	734	738
86	743	748	753	758	763	768	773	778	783	787
87	792	797	802	807	812	817	822	827	832	836
88	841	846	851	856	861	866	871	876	880	885
89	890	895	900	905	910	915	919	924	929	934
890	939	944	949	954	959	963	968	973	978	983
91	988	993	998	*002	*007	*012	*017	*022	*027	*032
92	95 036	041	046	051	056	061	066	071	075	080
93	085	090	095	100	105	109	114	119	124	129
94	134	139	143	148	153	158	163	168	173	177
95	182	187	192	197	202	207	211	216	221	226
96	231	236	240	245	250	255	260	265	270	274
97	279	284	289	294	299	303	308	313	318	323
98	328	332	337	342	347	352	357	361	366	371
99	376	381	386	390	395	400	405	410	415	419
900	424	429	434	439	444	448	453	458	463	468
	0	1	2	3	4	5	6	7	8	9

Prop. Pts.

	6	5	4
1	0.6	0.5	0.4
2	1.2	1.0	0.8
3	1.8	1.5	1.2
4	2.4	2.0	1.6
5	3.0	2.5	2.0
6	3.6	3.0	2.4
7	4.2	3.5	2.8
8	4.8	4.0	3.2
9	5.4	4.5	3.6

Prop. Pts.

N	0	1	2	3	4	5	6	7	8	9
900	95 424	429	434	439	444	448	453	458	463	468
01	472	477	482	487	492	497	501	506	511	516
02	521	525	530	535	540	545	550	554	559	564
03	569	574	578	583	588	593	598	602	607	612
04	617	622	626	631	636	641	646	650	655	660
05	665	670	674	679	684	689	694	698	703	708
06	713	718	722	727	732	737	742	746	751	756
07	761	766	770	775	780	785	789	794	799	804
08	809	813	818	823	828	832	837	842	847	852
09	856	861	866	871	875	880	885	890	895	899
910	904	909	914	918	923	928	933	938	942	947
11	952	957	961	966	971	976	980	985	990	995
12	999	*004	*009	*014	*019	*023	*028	*033	*038	*042
13	96 047	052	057	061	066	071	076	080	085	090
14	095	099	104	109	114	118	123	128	133	137
15	142	147	152	156	161	166	171	175	180	185
16	190	194	199	204	209	213	218	223	227	232
17	237	242	246	251	256	261	265	270	275	280
18	284	289	294	298	303	308	313	317	322	327
19	332	336	341	346	350	355	360	365	369	374
920	379	384	388	393	398	402	407	412	417	421
21	426	431	435	440	445	450	454	459	464	468
22	473	478	483	487	492	497	501	506	511	515
23	520	525	530	534	539	544	548	553	558	562
24	567	572	577	581	586	591	595	600	605	609
25	614	619	624	628	633	638	642	647	652	656
26	661	666	670	675	680	685	689	694	699	703
27	708	713	717	722	727	731	736	741	745	750
28	755	759	764	769	774	778	783	788	792	797
29	802	806	811	816	820	825	830	834	839	844
930	848	853	858	862	867	872	876	881	886	890
31	895	900	904	909	914	918	923	928	932	937
32	942	946	951	956	960	965	970	974	979	984
33	988	993	997	*002	*007	*011	*016	*021	*025	*030
34	97 035	039	044	049	053	058	063	067	072	077
35	081	086	090	095	100	104	109	114	118	123
36	128	132	137	142	146	151	155	160	165	169
37	174	179	183	188	192	197	202	206	211	216
38	220	225	230	234	239	243	248	253	257	262
39	267	271	276	280	285	290	294	299	304	308
940	313	317	322	327	331	336	340	345	350	354
41	359	364	368	373	377	382	387	391	396	400
42	405	410	414	419	424	428	433	437	442	447
43	451	456	460	465	470	474	479	483	488	493
44	497	502	506	511	516	520	525	529	534	539
45	543	548	552	557	562	566	571	575	580	585
46	589	594	598	603	607	612	617	621	626	630
47	635	640	644	649	653	658	663	667	672	676
48	681	685	690	695	699	704	708	713	717	722
49	727	731	736	740	745	749	754	759	763	768
950	772	777	782	786	791	795	800	804	809	813
	0	1	2	3	4	5	6	7	8	9

Prop. Pts.

	5	4
1	0.5	0.4
2	1.0	0.8
3	1.5	1.2
4	2.0	1.6
5	2.5	2.0
6	3.0	2.4
7	3.5	2.8
8	4.0	3.2
9	4.5	3.6

Prop. Pts.

	0	1	2	3	4	5	6	7	8	9
950	97 772	777	782	786	791	795	800	804	809	813
51	818	823	827	832	836	841	845	850	855	859
52	864	868	873	877	882	886	891	896	900	905
53	909	914	918	923	928	932	937	941	946	950
54	955	959	964	968	973	978	982	987	991	996
55	98 000	005	009	014	019	023	028	032	037	041
56	046	050	055	059	064	068	073	078	082	087
57	091	096	100	105	109	114	118	123	127	132
58	137	141	146	150	155	159	164	168	173	177
59	182	186	191	195	200	204	209	214	218	223
960	227	232	236	241	245	250	254	259	263	268
61	272	277	281	286	290	295	299	304	308	313
62	318	322	327	331	336	340	345	349	354	358
63	363	367	372	376	381	385	390	394	399	403
64	408	412	417	421	426	430	435	439	444	448
65	453	457	462	466	471	475	480	484	489	493
66	498	502	507	511	516	520	525	529	534	538
67	543	547	552	556	561	565	570	574	579	583
68	588	592	597	601	605	610	614	619	623	628
69	632	637	641	646	650	655	659	664	668	673
970	677	682	686	691	695	700	704	709	713	717
71	722	726	731	735	740	744	749	753	758	762
72	767	771	776	780	784	789	793	798	802	807
73	811	816	820	825	829	834	838	843	847	851
74	856	860	865	869	874	878	883	887	892	896
75	900	905	909	914	918	923	927	932	936	941
76	945	949	954	958	963	967	972	976	981	985
77	989	994	998	*003	*007	*012	*016	*021	*025	*029
78	99 034	038	043	047	052	056	061	065	069	074
79	078	083	087	092	096	100	105	109	114	118
980	123	127	131	136	140	145	149	154	158	162
81	167	171	176	180	185	189	193	198	202	207
82	211	216	220	224	229	233	238	242	247	251
83	255	260	264	269	273	277	282	286	291	295
84	300	304	308	313	317	322	326	330	335	339
85	344	348	352	357	361	366	370	374	379	383
86	388	392	396	401	405	410	414	419	423	427
87	432	436	441	445	449	454	458	463	467	471
88	476	480	484	489	493	498	502	506	511	515
89	520	524	528	533	537	542	546	550	555	559
990	564	568	572	577	581	585	590	594	599	603
91	607	612	616	621	625	629	634	638	642	647
92	651	656	660	664	669	673	677	682	686	691
93	695	699	704	708	712	717	721	726	730	734
94	739	743	747	752	756	760	765	769	774	778
95	782	787	791	795	800	804	808	813	817	822
96	826	830	835	839	843	848	852	856	861	865
97	870	874	878	883	887	891	896	900	904	909
98	913	917	922	926	930	935	939	944	948	952
99	957	961	965	970	974	978	983	987	991	996
1000	00 000	004	009	013	017	022	026	030	035	039
	0	1	2	3	4	5	6	7	8	9

Prop. Pts.

	5	4
1	0.5	0.4
2	1.0	0.8
3	1.5	1.2
4	2.0	1.6
5	2.5	2.0
6	3.0	2.4
7	3.5	2.8
8	4.0	3.2
9	4.5	3.6

Prop. Pts.

0° (180°) (359°) 179°

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	—	0.00 000	—	—	0.00 000	—	**60**
1	6.46 373	.00 000	6.46 373	3.53 627	.00 000	3.53 627	59
2	6.76 476	.00 000	6.76 476	3.23 524	.00 000	.23 524	58
3	6.94 085	.00 000	6.94 085	3.05 915	.00 000	.05 915	57
4	7.06 579	.00 000	7.06 579	2.93 421	.00 000	2.93 421	56
5	7.16 270	0.00 000	7.16 270	2.83 730	0.00 000	2.83 730	**55**
6	.24 188	.00 000	.24 188	.75 812	.00 000	.75 812	54
7	.30 882	.00 000	.30 882	.69 118	.00 000	.69 118	53
8	.36 682	.00 000	.36 682	.63 318	.00 000	.63 318	52
9	.41 797	.00 000	.41 797	.58 203	.00 000	.58 203	51
10	7.46 373	0.00 000	7.46 373	2.53 627	0.00 000	2.53 627	**50**
11	.50 512	.00 000	.50 512	.49 488	.00 000	.49 488	49
12	.54 291	.00 000	.54 291	.45 709	.00 000	.45 709	48
13	.57 767	.00 000	.57 767	.42 233	.00 000	.42 233	47
14	.60 985	.00 000	.60 986	.39 014	.00 000	.39 015	46
15	7.63 982	0.00 000	7.63 982	2.36 018	0.00 000	2.36 018	**45**
16	.66 784	.00 000	.66 785	.33 215	.00 000	.33 216	44
17	.69 417	9.99 999	.69 418	.30 582	.00 001	.30 583	43
18	.71 900	.99 999	.71 900	.28 100	.00 001	.28 100	42
19	.74 248	.99 999	.74 248	.25 752	.00 001	.25 752	41
20	7.76 475	9.99 999	7.76 476	2.23 524	0.00 001	2.23 525	**40**
21	.78 594	.99 999	.78 595	.21 405	.00 001	.21 406	39
22	.80 615	.99 999	.80 615	.19 385	.00 001	.19 385	38
23	.82 545	.99 999	.82 546	.17 454	.00 001	.17 455	37
24	.84 393	.99 999	.84 394	.15 606	.00 001	.15 607	36
25	7.86 166	9.99 999	7.86 167	2.13 833	0.00 001	2.13 834	**35**
26	.87 870	.99 999	.87 871	.12 129	.00 001	.12 130	34
27	.89 509	.99 999	.89 510	.10 490	.00 001	.10 491	33
28	.91 088	.99 999	.91 089	.08 911	.00 001	.08 912	32
29	.92 612	.99 998	.92 613	.07 387	.00 002	.07 388	31
30	7.94 084	9.99 998	7.94 086	2.05 914	0.00 002	2.05 916	**30**
31	.95 508	.99 998	.95 510	.04 490	.00 002	.04 492	29
32	.96 887	.99 998	.96 889	.03 111	.00 002	.03 113	28
33	.98 223	.99 998	.98 225	.01 775	.00 002	.01 777	27
34	.99 520	.99 998	.99 522	.00 478	.00 002	.00 480	26
35	8.00 779	9.99 998	8.00 781	1.99 219	0.00 002	1.99 221	**25**
36	.02 002	.99 998	.02 004	.97 996	.00 002	.97 998	24
37	.03 192	.99 997	.03 194	.96 806	.00 003	.96 808	23
38	.04 350	.99 997	.04 353	.95 647	.00 003	.95 650	22
39	.05 478	.99 997	.05 481	.94 519	.00 003	.94 522	21
40	8.06 578	9.99 997	8.06 581	1.93 419	0.00 003	1.93 422	**20**
41	.07 650	.99 997	.07 653	.92 347	.00 003	.92 350	19
42	.08 696	.99 997	.08 700	.91 300	.00 003	.91 304	18
43	.09 718	.99 997	.09 722	.90 278	.00 003	.90 282	17
44	.10 717	.99 996	.10 720	.89 280	.00 004	.89 283	16
45	8.11 693	9.99 996	8.11 696	1.88 304	0.00 004	1.88 307	**15**
46	.12 647	.99 996	.12 651	.87 349	.00 004	.87 353	14
47	.13 581	.99 996	.13 585	.86 415	.00 004	.86 419	13
48	.14 495	.99 996	.14 500	.85 500	.00 004	.85 505	12
49	.15 391	.99 996	.15 395	.84 605	.00 004	.84 609	11
50	8.16 268	9.99 995	8.16 273	1.83 727	0.00 005	1.83 732	**10**
51	.17 128	.99 995	.17 133	.82 867	.00 005	.82 872	9
52	.17 971	.99 995	.17 976	.82 024	.00 005	.82 029	8
53	.18 798	.99 995	.18 804	.81 196	.00 005	.81 202	7
54	.19 610	.99 995	.19 616	.80 384	.00 005	.80 390	6
56	8.20 407	9.99 994	8.20 413	1.79 587	0.00 006	1.79 593	**5**
56	.21 189	.99 994	.21 195	.78 805	.00 006	.78 811	4
57	.21 958	.99 994	.21 964	.78 036	.00 006	.78 042	3
58	.22 713	.99 994	.22 720	.77 280	.00 006	.77 287	2
59	.23 456	.99 994	.23 462	.76 538	.00 006	.76 544	1
60	8.24 186	9.99 993	8.24 192	1.75 808	0.00 007	1.75 814	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

90° (270°) (269°) 89°

1° (181°) (358°) **178°**

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	8.24 186	9.99 993	8.24 192	1.75 808	0.00 007	1.75 814	**60**
1	.24 903	.99 993	.24 910	.75 090	.00 007	.75 097	59
2	.25 609	.99 993	.25 616	.74 384	.00 007	.74 391	58
3	.26 304	.99 993	.26 312	.73 688	.00 007	.73 696	57
4	.26 988	.99 992	.26 996	.73 004	.00 008	.73 012	56
5	8.27 661	9.99 992	8.27 669	1.72 331	0.00 008	1.72 339	**55**
6	.28 324	.99 992	.28 332	.71 668	.00 008	.71 676	54
7	.28 977	.99 992	.28 986	.71 014	.00 008	.71 023	53
8	.29 621	.99 992	.29 629	.70 371	.00 008	.70 379	52
9	.30 255	.99 991	.30 263	.69 737	.00 009	.69 745	51
10	8.30 879	9.99 991	8.30 888	1.69 112	0.00 009	1.69 121	**50**
11	.31 495	.99 991	.31 505	.68 495	.00 009	.68 505	49
12	.32 103	.99 990	.32 112	.67 888	.00 010	.67 897	48
13	.32 702	.99 990	.32 711	.67 289	.00 010	.67 298	47
14	.33 292	.99 990	.33 302	.66 698	.00 010	.66 708	46
15	8.33 875	9.99 990	8.33 886	1.66 114	0.00 010	1.66 125	**45**
16	.34 450	.99 989	.34 461	.65 539	00.011	65 550	44
17	.35 018	.99 989	.35 029	.64 971	.00 011	.64 982	43
18	.35 578	.99 989	.35 590	.64 410	.00 011	.64 422	42
19	.36 131	.99 989	.36 143	.63 857	.00 011	.63 869	41
20	8.36 678	9.99 988	8.36 689	1.63 311	0.00 012	1.63 322	**40**
21	.37 217	.99 988	.37 229	.62 771	.00 012	.62 783	39
22	.37 750	.99 988	.37 762	.62 238	.00 012	.62 250	38
23	.38 276	.99 987	.38 289	.61 711	.00 013	.61 724	37
24	.38 796	.99 987	.38 809	.61 191	.00 013	.61 204	36
25	8.39 310	9.99 987	8.39 323	1.60 677	0.00 013	1.60 690	**35**
26	.39 818	.99 986	.39 832	.60 168	.00 014	.60 182	34
27	.40 320	.99 986	.40 334	.59 666	.00 014	.59 680	33
28	.40 816	.99 986	.40 830	.59 170	.00 014	.59 184	32
29	.41 307	.99 985	.41 321	.58 679	.00 015	.58 693	31
30	8.41 792	9.99 985	8.41 807	1.58 193	0.00 015	1.58 208	**30**
31	.42 272	.99 985	.42 287	.57 713	.00 015	.57 728	29
32	.42 746	.99 984	.42 762	.57 238	.00 016	.57 254	28
33	.43 216	.99 984	.43 232	.56 768	.00 016	.56 784	27
34	.43 680	.99 984	.43 696	.56 304	.00 016	.56 320	26
35	8.44 139	9.99 983	8.44 156	1.55 844	0.00 017	1.55 861	**25**
36	.44 594	.99 983	.44 611	.55 389	.00 017	.55 406	24
37	.45 044	.99 983	.45 061	.54 939	.00 017	.54 956	23
38	.45 489	.99 982	.45 507	.54 493	.00 018	.54 511	22
39	.45 930	.99 982	.45 948	.54 052	.00 018	.54 070	21
40	8.46 366	9.99 982	8.46 385	1.53 615	0.00 018	1.53 634	**20**
41	.46 799	.99 981	.46 817	.53 183	.00 019	.53 201	19
42	.47 226	.99 981	.47 245	.52 755	.00 019	.52 774	18
43	.47 650	.99 981	.47 669	.52 331	.00 019	.52 350	17
44	.48 069	.99 980	.48 089	.51 911	.00 020	.51 931	16
45	8.48 485	9.99 980	8.48 505	1.51 495	0.00 020	1.51 515	**15**
46	.48 896	.99 979	.48 917	.51 083	.00 021	.51 104	14
47	.49 304	.99 979	.49 325	.50 675	.00 021	.50 696	13
48	.49 708	.99 979	.49 729	.50 271	.00 021	.50 292	12
49	.50 108	.99 978	.50 130	.49 870	.00 022	.49 892	11
50	8.50 504	9.99 978	8.50 527	1.49 473	0.00 022	1.49 496	**10**
51	.50 897	.99 977	.50 920	.49 080	.00 023	.49 103	9
52	.51 287	.99 977	.51 310	.48 690	.00 023	.48 713	8
53	.51 673	.99 977	.51 696	.48 304	.00 023	.48 327	7
54	.52 055	.99 976	.52 079	.47 921	.00 024	.47 945	6
55	8.52 434	9.99 976	8.52 459	1.47 541	0.00 024	1.47 566	**5**
56	.52 810	.99 975	.52 835	.47 165	.00 025	.47 190	4
57	.53 183	.99 975	.53 208	.46 792	.00 025	.46 817	3
58	.53 552	.99 974	.53 578	.46 422	.00 026	.46 448	2
59	.53 919	.99 974	.53 945	.46 055	.00 026	.46 081	1
60	8.54 282	9.99 974	8.54 308	1.45 692	0.00 026	1.45 718	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

91° (271°) (268°) **88°**

2° (182°) (357°) **177°**

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	8.54 282	9.99 974	8.54 308	1.45 692	0.00 026	1.45 718	**60**
1	.54 642	.99 973	.54 669	.45 331	.00 027	.45 358	59
2	.54 999	.99 973	.55 027	.44 973	.00 027	.45 001	58
3	.55 354	.99 972	.55 382	.44 618	.00 028	.44 646	57
4	.55 705	.99 972	.55 734	.44 266	.00 028	.44 295	56
5	8.56 054	9.99 971	8.56 083	1.43 917	0.00 029	1.43 946	**55**
6	.56 400	.99 971	.56 429	.43 571	.00 029	.43 600	54
7	.56 743	.99 970	.56 773	.43 227	.00 030	.43 257	53
8	.57 084	.99 970	.57 114	.42 886	.00 030	.42 916	52
9	.57 421	.99 969	.57 452	.42 548	.00 031	.42 579	51
10	8.57 757	9.99 969	8.57 788	1.42 212	0.00 031	1.42 243	**50**
11	.58 089	.99 968	.58 121	.41 879	.00 032	.41 911	49
12	.58 419	.99 968	.58 451	.41 549	.00 032	.41 581	48
13	.58 747	.99 967	.58 779	.41 221	.00 033	.41 253	47
14	.59 072	.99 967	.59 105	.40 895	.00 033	.40 928	46
15	8.59 395	9.99 967	8.59 428	1.40 572	0.00 033	1.40 605	**45**
16	.59 715	.99 966	.59 749	.40 251	.00 034	.40 285	44
17	.60 033	.99 966	.60 068	.39 932	.00 034	.39 967	43
18	.60 349	.99 965	.60 384	.39 616	.00 035	.39 651	42
19	.60 662	.99 964	.60 698	.39 302	.00 036	.39 338	41
20	8.60 973	9.99 964	8.61 009	1.38 991	0.00 036	1.39 027	**40**
21	.61 282	.99 963	.61 319	.38 681	.00 037	.38 718	39
22	.61 589	.99 963	.61 626	.38 374	.00 037	.38 411	38
23	.61 894	.99 962	.61 931	.38 069	.00 038	.38 106	37
24	.62 196	.99 962	.62 234	.37 766	.00 038	.37 804	36
25	8.62 497	9.99 961	8.62 535	1.37 465	0.00 039	1.37 503	**35**
26	.62 795	.99 961	.62 834	.37 166	.00 039	.37 205	34
27	.63 091	.99 960	.63 131	.36 869	.00 940	.36 909	33
28	.63 385	.99 960	.63 426	.36 574	.00 040	.36 615	32
29	.63 678	.99 959	.63 718	.36 282	.00 041	.36 322	31
30	8.63 968	9.99 959	8.64 009	1.35 991	0.00 041	1.36 032	**30**
31	.64 256	.99 958	.64 298	.35 702	.00 042	.35 744	29
32	.64 543	.99 958	.64 585	.35 415	.00 042	.35 457	28
33	.64 827	.99 957	.64 870	.35 130	.00 043	.35 173	27
34	.65 110	.99 956	.65 154	.34 846	.00 044	.34 890	26
35	8.65 391	9.99 956	8.65 435	1.34 565	0.00 044	1.34 609	**25**
36	.65 670	.99 955	.65 715	.34 285	.00 045	.34 330	24
37	.65 947	.99 955	.65 993	.34 007	.00 045	.34 053	23
38	.66 223	.99 954	.66 269	.33 731	.00 046	.33 777	22
39	.66 497	.99 954	.66 543	.33 457	.00 046	.33 503	21
40	8.66 769	9.99 953	8.66 816	1.33 184	0.00 047	1.33 231	**20**
41	.67 039	.99 952	.67 087	.32 913	.00 048	.32 961	19
42	.67 308	.99 952	.67 356	.32 644	.00 048	.32 692	18
43	.67 575	.99 951	.67 624	.32 376	.00 049	.32 425	17
44	.67 841	.99 951	.67 890	.32 110	.00 049	.32 159	16
45	8.68 104	9.99 950	8.68 154	1.31 846	0.00 050	1.31 896	**15**
46	.68 367	.99 949	.68 417	.31 583	.00 051	.31 633	14
47	.68 627	.99 949	.68 678	.31 322	.00 051	.31 373	13
48	.68 886	.99 948	.68 938	.31 062	.00 052	.31 114	12
49	.69 144	.99 948	.69 196	.30 804	.00 052	.30 856	11
50	8.69 400	9.99 947	8.69 453	1.30 547	0.00 053	1.30 600	**10**
51	.69 654	.99 946	.69 708	.30 292	.00 054	.30 346	9
52	.69 907	.99 946	.69 962	.30 038	.00 054	.30 093	8
53	.70 159	.99 945	.70 214	.29 786	.00 055	.29 841	7
54	.70 409	.99 944	.70 465	.29 535	.00 056	.29 591	6
55	8.70 658	9.99 944	8.70 714	1.29 286	0.00 056	1.29 342	**5**
56	.70 905	.99 943	.70 962	.29 038	.00 057	.29 095	4
57	.71 151	.99 942	.71 208	.28 792	.00 058	.28 849	3
58	.71 395	.99 942	.71 453	.28 547	.00 058	.28 605	2
59	.71 638	.99 941	.71 697	.28 303	.00 059	.28 362	1
60	8.71 880	9.99 940	8.71 940	1.28 060	0.00 060	1.28 120	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

92° (272°) (267°) **87°**

3° (183°) (356°) 176°

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	8.71 880	9.99 940	8.71 940	1.28 060	0.00 060	1.28 120	**60**
1	.72 120	.99 940	.72 181	.27 819	.00 060	.27 880	59
2	.72 359	.99 939	.72 420	.27 580	.00 061	.27 641	58
3	.72 597	.99 938	.72 659	.27 341	.00 062	.27 403	57
4	.72 834	.99 938	.72 896	.27 104	.00 062	.27 166	56
5	8.73 069	9.99 937	8.73 132	1.26 868	0.00 063	1.26 931	**55**
6	.73 303	.99 936	.73 366	.26 634	.00 064	.26 697	54
7	.73 535	.99 936	.73 600	.26 400	.00 064	.26 465	53
8	.73 767	.99 935	.73 832	.26 168	.00 065	.26 233	52
9	.73 997	.99 934	.74 063	.25 937	.00 066	.26 003	51
10	8.74 226	9.99 934	8.74 292	1.25 708	0.00 066	1.25 774	**50**
11	.74 454	.99 933	.74 521	.25 479	.00 067	.25 546	49
12	.74 680	.99 932	.74 748	.25 252	.00 068	.25 320	48
13	.74 906	.99 932	.74 974	.25 026	.00 068	.25 094	47
14	.75 130	.99 931	.75 199	.24 801	.00 069	.24 870	46
15	8.75 353	9.99 930	8.75 423	1.24 577	0.00 070	1.24 647	**45**
16	.75 575	.99 929	.75 645	.24 355	.00 071	.24 425	44
17	.75 795	.99 929	.75 867	.24 133	.00 071	.24 205	43
18	.76 015	.99 928	.76 087	.23 913	.00 072	.23 985	42
19	.76 234	.99 927	.76 306	.23 694	.00 073	.23 766	41
20	8.76 451	9.99 926	8.76 525	1.23 475	0.00 074	1.23 549	**40**
21	.76 667	.99 926	.76 742	.23 258	.00 074	.23 333	39
22	.76 883	.99 925	.76 958	.23 042	.00 075	.23 117	38
23	.77 097	.99 924	.77 173	.22 827	.00 076	.22 903	37
24	.77 310	.99 923	.77 387	.22 613	.00 077	.22 690	36
25	8.77 522	9.99 923	8.77 600	1.22 400	0.00 077	1.22 478	**35**
26	.77 733	.99 922	.77 811	.22 189	.00 078	.22 267	34
27	.77 943	.99 921	.78 022	.21 978	.00 079	.22 057	33
28	.78 152	.99 920	.78 232	.21 768	.00 080	.21 848	32
29	.78 360	.99 920	.78 441	.21 559	.00 080	.21 640	31
30	8.78 568	9.99 919	8.78 649	1.21 351	0.00 081	1.21 432	**30**
31	.78 774	.99 918	.78 855	.21 145	.00 082	.21 226	29
32	.78 979	.99 917	.79 061	.20 939	.00 083	.21 021	28
33	.79 183	.99 917	.79 266	.20 734	.00 083	.20 817	27
34	.79 386	.99 916	.79 470	.20 530	.00 084	.20 614	26
35	8.79 588	9.99 915	8.79 673	1.20 327	0.00 085	1.20 412	**25**
36	.79 789	.99 914	.79 875	.20 125	.00 086	.20 211	24
37	.79 990	.99 913	.80 076	.19 924	.00 087	.20 010	23
38	.80 189	.99 913	.80 277	.19 723	.00 087	.19 811	22
39	.80 388	.99 912	.80 476	.19 524	.00 088	.19 612	21
40	8.80 585	9.99 911	8.80 674	1.19 326	0.00 089	1.19 415	**20**
41	.80 782	.99 910	.80 872	.19 128	.00 090	.19 218	19
42	.80 978	.99 909	.81 068	.18 932	.00 091	.19 022	18
43	.81 173	.99 909	.81 264	.18 736	.00 091	.18 827	17
44	.81 367	.99 908	.81 459	.18 541	.00 092	.18 633	16
45	8.81 560	9.99 907	8.81 653	1.18 347	0.00 093	1.18 440	**15**
46	.81 752	.99 906	.81 846	.18 154	.00 094	.18 248	14
47	.81 944	.99 905	.82 038	.17 962	.00 095	.18 056	13
48	.82 134	.99 904	.82 230	.17 770	.00 096	.17 866	12
49	.82 324	.99 904	.82 420	.17 580	.00 096	.17 676	11
50	8.82 513	9.99 903	8.82 610	1.17 390	0.00 097	1.17 487	**10**
51	.82 701	.99 902	.82 799	.17 201	.00 098	.17 299	9
52	.82 888	.99 901	.82 987	.17 013	.00 099	.17 112	8
53	.83 075	.99 900	.83 175	.16 825	.00 100	.16 925	7
54	.83 261	.99 899	.83 361	.16 639	.00 101	.16 739	6
55	8.83 446	9.99 898	8.83 547	1.16 453	0.00 102	1.16 554	**5**
56	.83 630	.99 898	.83 732	.16 268	.00 102	.16 370	4
57	.83 813	.99 897	.83 916	.16 084	.00 103	.16 187	3
58	.83 996	.99 896	.84 100	.15 900	.00 104	.16 004	2
59	.84 177	.99 895	.84 282	.15 718	.00 105	.15 823	1
60	8.84 358	9.99 894	8.84 464	1.15 536	0.00 106	1.15 642	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

93° (273°) (266°) 86°

4° (184°) (355°) 175°

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	8.84 358	9.99 894	8.84 464	1.15 536	0.00 106	1.15 642	**60**
1	.84 539	.99 893	.84 646	.15 354	.00 107	.15 461	59
2	.84 718	.99 892	.84 826	.15 174	.00 108	.15 282	58
3	.84 897	.99 891	.85 006	.14 994	.00 109	.15 103	57
4	.85 075	.99 891	.85 185	.14 815	.00 109	.14 925	56
5	8.85 252	9.99 890	8.85 363	1.14 637	0.00 110	1.14 748	**55**
6	.85 429	.99 889	.85 540	.14 460	.00 111	.14 571	54
7	.85 605	.99 888	.85 717	.14 283	.00 112	.14 395	53
8	.85 780	.99 887	.85 893	.14 107	.00 113	.14 220	52
9	.85 955	.99 886	.86 069	.13 931	.00 114	.14 045	51
10	8.86 128	9.99 885	8.86 243	1.13 757	0.00 115	1.13 872	**50**
11	.86 301	.99 884	.86 417	.13 583	.00 116	.13 699	49
12	.86 474	.99 883	.86 591	.13 409	.00 117	.13 526	48
13	.86 645	.99 882	.86 763	.13 237	.00 118	.13 355	47
14	.86 816	.99 881	.86 935	.13 065	.00 119	.13 184	46
15	8.86 987	9.99 880	8.87 106	1.12 894	0.00 120	1.13 013	**45**
16	.87 156	.99 879	.87 277	.12 723	.00 121	.12 844	44
17	.87 325	.99 879	.87 447	.12 553	.00 121	.12 675	43
18	.87 494	.99 878	.87 616	.12 384	.00 122	.12 506	42
19	.87 661	.99 877	.87 785	.12 215	.00 123	.12 339	41
20	8.87 829	9.99 876	8.87 953	1.12 047	0.00 124	1.12 171	**40**
21	.87 995	.99 875	.88 120	.11 880	.00 125	.12 005	39
22	.88 161	.99 874	.88 287	.11 713	00 126	.11 839	38
23	.88 326	.99 873	.88 453	.11 547	.00 127	.11 674	37
24	.88 490	.99 872	.88 618	.11 382	.00 128	.11 510	36
25	8.88 654	9.99 871	8.88 783	1.11 217	0.00 129	1.11 346	**35**
26	.88 817	.99 870	.88 948	.11 052	.00 130	.11 183	34
27	.88 980	.99 869	.89 111	.10 889	.00 131	.11 020	33
28	.89 142	.99 868	.89 274	.10 726	.00 132	.10 858	32
29	.89 304	.99 867	.89 437	.10 563	.00 133	.10 696	31
30	8.89 464	9.99 866	8.89 598	1.10 402	0.00 134	1.10 536	**30**
31	.89 625	.99 865	.89 760	.10 240	.00 135	.10 375	29
32	.89 784	.99 864	.89 920	.10 080	.00 136	.10 216	28
33	.89 943	.99 863	.90 080	.09 920	.00 137	.10 057	27
34	.90 102	.99 862	.90 240	.09 760	.00 138	.09 898	26
35	8.90 260	9.99 861	8.90 399	1.09 601	0.00 139	1.09 740	**25**
36	.90 417	.99 860	.90 557	.09 443	.00 140	.09 583	24
37	.90 574	.99 859	.90 715	.09 285	.00 141	.09 426	23
38	.90 730	.99 858	.90 872	.09 128	.00 142	.09 270	22
39	.90 885	.99 857	.91 029	.08 971	.00 143	.09 115	21
40	8.91 040	9.99 856	8.91 185	1.08 815	0.00 144	1.08 960	**20**
41	.91 195	.99 855	.91 340	.08 660	.00 145	.08 805	19
42	.91 349	.99 854	.91 495	.08 505	.00 146	.08 651	18
43	.91 502	.99 853	.91 650	.08 350	.00 147	.08 498	17
44	.91 655	.99 852	.91 803	.08 197	.00 148	.08 345	16
45	8.91 807	9.99 851	8.91 957	1.08 043	0.00 149	1.08 193	**15**
46	.91 959	.99 850	.92.110	.07 890	.00 150	.08 041	14
47	.92 110	.99 848	.92 262	.07 738	.00 152	.07 890	13
48	.92 261	.99 847	.92 414	.07 586	.00 153	.07 739	12
49	.92 411	.99 846	.92 565	.07 435	.00 154	.07 589	11
50	8.92 561	9.99 845	8.92 716	1.07 284	0.00 155	1.07 439	**10**
51	.92 710	.99 844	.92 866	.07 134	.00 156	.07 290	9
52	.92 859	.99 843	.93 016	.06 984	.00 157	.07 141	8
53	.93 007	.99 842	.93 165	.06 835	.00 158	.06 993	7
54	.93 154	.99 841	.93 313	.06 687	.00 159	.06 846	6
55	8.93 301	9.99 840	8.93 462	1.06 538	0.00 160	1.06 699	**5**
56	.93 448	.99 839	.93 609	.06 391	.00 161	.06 552	4
57	.93 594	.99 838	.93 756	.06 244	.00 162	.06 406	3
58	.93 740	.99 837	.93 903	.06 097	.00 163	.06 260	2
59	.93 885	.99 836	.94 049	.05 951	.00 164	.06 115	1
60	8.94 030	9.99 834	8.94 195	1.05 805	0.00 166	1.05 970	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

94° (274°) (265°) 85°

5° (185°) (354°) 174°

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	8.94 030	9.99 834	8.94 195	1.05 805	0.00 166	1.05 970	**60**
1	.94 174	.99 833	.94 340	.05 660	.00 167	.05 826	59
2	.94 317	.99 832	.94 485	.05 515	.00 168	.05 683	58
3	.94 461	.99 831	.94 630	.05 370	.00 169	.05 539	57
4	.94 603	.99 830	.94 773	.05 227	.00 170	.05 397	56
5	8.94 746	9.99 829	8.94 917	1.05 083	0.00 171	1.05 254	**55**
6	.94 887	.99 828	.95 060	.04 940	.00 172	.05 113	54
7	.95 029	.99 827	.95 202	.04 798	.00 173	.04 971	53
8	.95 170	.99 825	.95 344	.04 656	.00 175	.04 830	52
9	.95 310	.99 824	.95 486	.04 514	.00 176	.04 690	51
10	8.95 450	9.99 823	8.95 627	1.04 373	0.00 177	1.04 550	**50**
11	.95 589	.99 822	.95 767	.04 233	.00 178	.04 411	49
12	.95 728	.99 821	.95 908	.04 092	.00 179	.04 272	48
13	.95 867	.99 820	.96 047	.03 953	.00 180	.04 133	47
14	.96 005	.99 819	.96 187	.03 813	.00 181	.03 995	46
15	8.96 143	9.99 817	8.96 325	1.03 675	0.00 183	1.03 857	**45**
16	.96 280	.99 816	.96 464	.03 536	.00 184	.03 720	44
17	.96 417	.99 815	.96 602	.03 398	.00 185	.03 583	43
18	.96 553	.99 814	.96 739	.03 261	.00 186	.03 447	42
19	.96 689	.99 813	.96 877	.03 123	.00 187	.03 311	41
20	8.96 825	9.99 812	8.97 013	1.02 987	0.00 188	1.03 175	**40**
21	.96 960	.99 810	.97 150	.02 850	.00 190	.03 040	39
22	.97 095	.99 809	.97 285	.02 715	.00 191	.02 905	38
23	.97 229	.99 808	.97 421	.02 579	.00 192	.02 771	37
24	.97 363	.99 807	.97 556	.02 444	.00 193	.02 637	36
25	8.97 496	9.99 806	8.97 691	1.02 309	0.00 194	1.02 504	**35**
26	.97 629	.99 804	.97 825	.02 175	.00 196	.02 371	34
27	.97 762	.99 803	.97 959	.02 041	.00 197	.02 238	33
28	.97 894	.99 802	.98 092	.01 908	.00 198	.02 106	32
29	.98 026	.99 801	.98 225	.01 775	.00 199	.01 974	31
30	8.98 157	9.99 800	8.98 358	1.01 642	0.00 200	1.01 843	**30**
31	.98 288	.99 798	.98 490	.01 510	.00 202	.01 712	29
32	.98 419	.99 797	.98 622	.01 378	.00 203	.01 581	28
33	.98 549	.99 796	.98 753	.01 247	.00 204	.01 451	27
34	.98 679	.99 795	.98 884	.01 116	.00 205	.01 321	26
35	8.98 808	9.99 793	8.99 015	1.00 985	0.00 207	1.01 192	**25**
36	.98 937	.99 792	.99 145	.00 855	.00 208	.01 063	24
37	.99 066	.99 791	.99 275	.00 725	.00 209	.00 934	23
38	.99 194	.99 790	.99 405	.00 595	.00 210	.00 806	22
39	.99 322	.99 788	.99 534	.00 466	.00 212	.00 678	21
40	8.99 450	9.99 787	8.99 662	1.00 338	0.00 213	1.00 550	**20**
41	.99 577	.99 786	.99 791	.00 209	.00 214	.00 423	19
42	.99 704	.99 785	.99 919	.00 081	.00 215	.00 296	18
43	.99 830	.99 783	9.00 046	0.99 954	.00 217	.00 170	17
44	.99 956	.99 782	.00 174	.99 826	.00 218	.00 044	16
45	9.00 082	9.99 781	9.00 301	0.99 699	0.00 219	0.99 918	**15**
46	.00 207	.99 780	.00 427	.99 573	.00 220	.99 793	14
47	.00 332	.99 778	.00 553	.99 447	.00 222	.99 668	13
48	.00 456	.99 777	.00 679	.99 321	.00 223	.99 544	12
49	.00 581	.99 776	.00 805	.99 195	.00 224	.99 419	11
50	9.00 704	9.99 775	9.00 930	0.99 070	0.00 225	0.99 296	**10**
51	.00 828	.99 773	.01 055	.98 945	.00 227	.99 172	9
52	.00 951	.99 772	.01 179	.98 821	.00 228	.99 049	8
53	.01 074	.99 771	.01 303	.98 697	.00 229	.98 926	7
54	.01 196	.99 769	.01 427	.98 573	.00 231	.98 804	6
55	9.01 318	9.99 768	9.01 550	0.98 450	0.00 232	0.98 682	**5**
56	.01 440	.99 767	.01 673	.98 327	.00 233	.98 560	4
57	.01 561	.99 765	.01 796	.98 204	.00 235	.98 439	3
58	.01 682	.99 764	.01 918	.98 082	.00 236	.98 318	2
59	.01 803	.99 763	.02 040	.97 960	.00 237	.98 197	1
60	9.01 923	9.99 761	9.02 162	0.97 838	0.00 239	0.98 077	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

95° (275°) (264°) 84°

6° (186°) (353°) **173°**

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.01 923	9.99 761	9.02 162	0.97 838	0.00 239	0.98 077	**60**
1	.02 043	.99 760	.02 283	.97 717	00 240	.97 957	59
2	.02 163	.99 759	.02 404	.97 596	.00 241	.97 837	58
3	.02 283	.99 757	.02 525	.97 475	.00 243	.97 717	57
4	.02 402	.99 756	.02 645	.97 355	.00 244	.97 598	56
5	9.02 520	9.99 755	9.02 766	0.97 234	0.00 245	0.97 480	**55**
6	.02 639	.99 753	.02 885	.97 115	.00 247	.97 361	54
7	.02 757	.99 752	.03 005	.96 995	.00 248	.97 243	53
8	.02 874	.99 751	.03 124	.96 876	.00 249	.97 126	52
9	.02 992	.99 749	.03 242	.96 758	.00 251	.97 008	51
10	9.03 109	9.99 748	9.03 361	0.96 639	0.00 252	0.96 891	**50**
11	.03 226	.99 747	.03 479	.96 521	.00 253	.96 774	49
12	.03 342	.99 745	.03 597	.96 403	.00 255	.96 658	48
13	.03 458	.99 744	.03 714	.96 286	.00 256	.96 542	47
14	.03 574	.99 742	.03 832	.96 168	.00 258	.96 426	46
15	9.03 690	9.99 741	9.03 948	0.96 052	0.00 259	0.96 310	**45**
16	.03 805	.99 740	.04 065	.95 935	.00 260	.96 195	44
17	.03 920	.99 738	.04 181	.95 819	.00 262	.96 080	43
18	.04 034	.99 737	.04 297	.95 703	.00 263	.95 966	42
19	.04 149	.99 736	.04 413	.95 587	.00 264	.95 851	41
20	9.04 262	9.99 734	9.04 528	0.95 472	0.00 266	0.95 738	**40**
21	.04 376	.99 733	.04 643	.95 357	.00 267	.95 624	39
22	.04 490	.99 731	.04 758	.95 242	.00 269	.95 510	38
23	.04 603	.99 730	.04 873	.95 127	.00 270	.95 397	37
24	.04 715	.99 728	.04 987	.95 013	.00 272	.95 285	36
25	9.04 828	9.99 727	9.05 101	0.94 899	0.00 273	0.95 172	**35**
26	.04 940	.99 726	.05 214	.94 786	.00 274	.95 060	34
27	.05 052	.99 724	.05 328	.94 672	.00 276	.94 948	33
28	.05 164	.99 723	.05 441	.94 559	.00 277	.94 836	32
29	.05 275	.99 721	.05 553	.94 447	.00 279	.94 725	31
30	9.05 386	9.99 720	9.05 666	0.94 334	0.00 280	0.94 614	**30**
31	.05 497	.99 718	.05 778	.94 222	.00 282	.94 503	29
32	.05 607	.99 717	.05 890	.94 110	.00 283	.94 393	28
33	.05 717	.99 716	.06 002	.93 998	.00 284	.94 283	27
34	.05 827	.99 714	.06 113	.93 887	.00 286	.94 173	26
35	9.05 937	9.99 713	9.06 224	0.93 776	0.00 287	0.94 063	**25**
36	.06 046	.99 711	.06 335	.93 665	.00 289	.93 954	24
37	.06 155	.99 710	.06 445	.93 555	.00 290	.93 845	23
38	.06 264	.99 708	.06 556	.93 444	.00 292	.93 736	22
39	.06 372	.99 707	.06 666	.93 334	.00 293	.93 628	21
40	9.06 481	9.99 705	9.06 775	0.93 225	0.00 295	0.93 519	**20**
41	.06 589	.99 704	.06 885	.93 115	.00 296	.93 411	19
42	.06 696	.99 702	.06 994	.93 006	.00 298	.93 304	18
43	.06 804	.99 701	.07 103	.92 897	.00 299	.93 196	17
44	.06 911	.99 699	.07 211	.92 789	.00 301	.93 089	16
45	9.07 018	9.99 698	9.07 320	0.92 680	0.00 302	0.92 982	**15**
46	.07 124	.99 696	.07 428	.92 572	.00 304	.92 876	14
47	.07 231	.99 695	.07 536	.92 464	.00 305	.92 769	13
48	.07 337	.99 693	.07 643	.92 357	00.307	.92 663	12
49	.07 442	.99 692	.07 751	.92 249	.00 308	.92 558	11
50	9.07 548	9.99 690	9.07 858	0.92 142	0.00 310	0.92 452	**10**
51	.07 653	.99 689	.07 964	.92 036	.00 311	.92 347	9
52	.07 758	.99 687	.08 071	.91 929	.00 313	.92 242	8
53	.07 863	.99 686	.08 177	.91 823	.00 314	.92 137	7
54	.07 968	.99 684	.08 283	.91 717	.00 316	.92 032	6
55	9.08 072	9.99 683	9.08 389	0.91 611	0.00 317	0.91 928	**5**
56	.08 176	.99 681	.08 495	.91 505	.00 319	.91 824	4
57	.08 280	.99 680	.08 600	.91 400	.00 320	.91 720	3
58	.08 383	.99 678	.08 705	.91 295	.00 322	.91 617	2
59	.08 486	.99 677	.08 810	.91 190	.00 323	.91 514	1
60	9.08 589	9.99 675	9.08 914	0.91 086	0.00 325	0.91 411	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

96° (276°) (263°) **83°**

7° (187°) | (352°) **172°**

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.08 589	9.99 675	9.08 914	0.91 086	0.00 325	0.91 411	**60**
1	.08 692	.99 674	.09 019	.90 981	.00 326	.91 308	59
2	.08 795	.99 672	.09 123	.90 877	.00 328	.91 205	58
3	.08 897	.99 670	.09 227	.90 773	.00 330	.91 103	57
4	.08 999	.99 669	.09 330	.90 670	.00 331	.91 001	56
5	9.09 101	9.99 667	9.09 434	0.90 566	0.00 333	0.90 899	**55**
6	.09 202	.99 666	.09 537	.90 463	.00 334	.90 798	54
7	.09 304	.99 664	.09 640	.90 360	.00 336	.90 696	53
8	.09 405	.99 663	.09 742	.90 258	.00 337	.90 595	52
9	.09 506	.99 661	.09 845	.90 155	.00 339	.90 494	51
10	9.09 606	9.99 659	9.09 947	0.90 053	0.00 341	0.90 394	**50**
11	.09 707	.99 658	.10 049	.89 951	.00 342	.90 293	49
12	.09 807	.99 656	.10 150	.89 850	.00 344	.90 193	48
13	.09 907	.99 655	.10 252	.89 748	.00 345	.90 093	47
14	.10 006	.99 653	.10 353	.89 647	.00 347	.89 994	46
15	9.10 106	9.99 651	9.10 454	0.89 546	0.00 349	0.89 894	**45**
16	.10 205	.99 650	.10 555	.89 445	.00 350	.89 795	44
17	.10 304	.99 648	.10 656	.89 344	.00 352	.89 696	43
18	.10 402	.99 647	.10 756	.89 244	.00 353	.89 598	42
19	.10 501	.99 645	.10 856	.89 144	.00 355	.89 499	41
20	9.10 599	9.99 643	9.10 956	0.89 044	0.00 357	0.89 401	**40**
21	.10 697	.99 642	.11 056	.88 944	.00 358	.89 303	39
22	.10 795	.99 640	.11 155	.88 845	.00 360	.89 205	38
23	.10 893	.99 638	.11 254	.88 746	.00 362	.89 107	37
24	.10 990	.99 637	.11 353	.88 647	.00 363	.89 010	36
25	9.11 087	9.99 635	9.11 452	0.88 548	0.00 365	0.88 913	**35**
26	.11 184	.99 633	.11 551	.88 449	.00 367	.88 816	34
27	.11 281	.99 632	.11 649	.88 351	.00 368	.88 719	33
28	.11 377	.99 630	.11 747	.88 253	.00 370	.88 623	32
29	.11 474	.99 629	.11 845	.88 155	.00 371	.88 526	31
30	9.11 570	9.99 627	9.11 943	0.88 057	0.00 373	0.88 430	**30**
31	.11 666	.99 625	.12 040	.87 960	.00 375	.88 334	29
32	.11 761	.99 624	.12 138	.87 862	.00 376	.88 239	28
33	.11 857	.99 622	.12 235	.87 765	.00 378	.88 143	27
34	.11 952	.99 620	.12 332	.87 668	.00 380	.88 048	26
35	9.12 047	9.99 618	9.12 428	0.87 572	0.00 382	0.87 953	**25**
36	.12 142	.99 617	.12 525	.87 475	.00 383	.87 858	24
37	.12 236	.99 615	.12 621	.87 379	.00 385	.87 764	23
38	.12 331	.99 613	.12 717	.87 283	.00 387	.87 669	22
39	.12 425	.99 612	.12 813	.87 187	.00 388	.87 575	21
40	9.12 519	9.99 610	9.12 909	0.87 091	0.00 390	0.87 481	**20**
41	.12 612	.99 608	.13 004	.86 996	.00 392	.87 388	19
42	.12 706	.99 607	.13 099	.86 901	.00 393	.87 294	18
43	.12 799	.99 605	.13 194	.86 806	.00 395	.87 201	17
44	.12 892	.99 603	.13 289	.86 711	.00 397	.87 108	16
45	9.12 985	9.99 601	9.13 384	0.86 616	0.00 399	0.87 015	**15**
46	.13 078	.99 600	.13 478	.86 522	.00 400	.86 922	14
47	.13 171	.99 598	.13 573	.86 427	.00 402	.86 829	13
48	.13 263	.99 596	.13 667	.86 333	.00 404	.86 737	12
49	.13 355	.99 595	.13 761	.86 239	.00 405	.86 645	11
50	9.13 447	9.99 593	9.13 854	0.86 146	0.00 407	0.86 553	**10**
51	.13 539	.99 591	.13 948	.86 052	.00 409	.86 461	9
52	.13 630	.99 589	.14 041	.85 959	.00 411	.86 370	8
53	.13 722	.99 588	.14 134	.85 866	.00 412	.86 278	7
54	.13 813	.99 586	.14 227	.85 773	.00 414	.86 187	6
55	9.13 904	9.99 584	9.14 320	0.85 680	0.00 416	0.86 096	**5**
56	.13 994	.99 582	.14 412	.85 588	.00 418	.86 006	4
57	.14 085	.99 581	.14 504	.85 496	.00 419	.85 915	3
58	.14 175	.99 579	.14 597	.85 403	.00 421	.85 825	2
59	.14 266	.99 577	.14 688	.85 312	.00 423	.85 734	1
60	9.14 356	9.99 575	9.14 780	0.85 220	0.00 425	0.85 644	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

97° (277°) | (262°) **82°**

8° (188°) (351°) 171°

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.14 356	9.99 575	9.14 780	0.85 220	0.00 425	0.85 644	**60**
1	.14 445	.99 574	.14 872	.85 128	.00 426	.85 555	59
2	.14 535	.99 572	.14 963	.85 037	.00 428	.85 465	58
3	.14 624	.99 570	.15 054	.84 946	.00 430	.85 376	57
4	.14 714	.99 568	.15 145	.84 855	.00 432	.85 286	56
5	9.14 803	9.99 566	9.15 236	0.84 764	0.00 434	0.85 197	**55**
6	.14 891	.99 565	.15 327	.84 673	.00 435	.85 109	54
7	.14 980	.99 563	.15 417	.84 583	.00 437	.85 020	53
8	.15 069	.99 561	.15 508	.84 492	.00 439	.84 931	52
9	.15 157	.99 559	.15 598	.84 402	.00 441	.84 843	51
10	9.15 245	9.99 557	9.15 688	0.84 312	0.00 443	0.84 755	**50**
11	.15 333	.99 556	.15 777	.84 223	.00 444	.84 667	49
12	.15 421	.99 554	.15 867	.84 133	.00 446	.84 579	48
13	.15 508	.99 552	.15 956	.84 044	.00 448	.84 492	47
14	.15 596	.99 550	.16 046	.83 954	.00 450	.84 404	46
15	9.15 683	9.99 548	9.16 135	0.83 865	0.00 452	0.84 317	**45**
16	.15 770	.99 546	.16 224	.83 776	.00 454	.84 230	44
17	.15 857	.99 545	.16 312	.83 688	.00 455	.84 143	43
18	.15 944	.99 543	.16 401	.83 599	.00 457	.84 056	42
19	.16 030	.99 541	.16 489	.83 511	.00 459	.83 970	41
20	9.16 116	9.99 539	9.16 577	0.83 423	0.00 461	0.83 884	**40**
21	.16 203	.99 537	.16 665	.83 335	.00 463	.83 797	39
22	.16 289	.99 535	.16 753	.83 247	.00 465	.83 711	38
23	.16 374	.99 533	.16 841	.83 159	.00 467	.83 626	37
24	.16 460	.99 532	.16 928	.83 072	.00 468	.83 540	36
25	9.16 545	9.99 530	9.17 016	0.82 984	0.00 470	0.83 455	**35**
26	.16 631	.99 528	.17 103	.82 897	.00 472	.83 369	34
27	.16 716	.99 526	.17 190	.82 810	.00 474	.83 284	33
28	.16 801	.99 524	.17 277	.82 723	.00 476	.83 199	32
29	.16 886	.99 522	.17 363	.82 637	.00 478	.83 114	31
30	9.16 970	9.99 520	9.17 450	0.82 550	0.00 480	0.83 030	**30**
31	.17 055	.99 518	.17 536	.82 464	.00 482	.82 945	29
32	.17 139	.99 517	.17 622	.82 378	.00 483	.82 861	28
33	.17 223	.99 515	.17 708	.82 292	.00 485	.82 777	27
34	.17 307	.99 513	.17 794	.82 206	.00 487	.82 693	26
35	9.17 391	9.99 511	9.17 880	0.82 120	0.00 489	0.82 609	**25**
36	.17 474	.99 509	.17 965	.82 035	.00 491	.82 526	24
37	.17 558	.99 507	.18 051	.81 949	.00 493	.82 442	23
38	.17 641	.99 505	.18 136	.81 864	.00 495	.82 359	22
39	.17 724	.99 503	.18 221	.81 779	.00 497	.82 276	21
40	9.17 807	9.99 501	9.18 306	0.81 694	0.00 499	0.82 193	**20**
41	.17 890	.99 499	.18 391	.81 609	.00 501	.82 110	19
42	.17 973	.99 497	.18 475	.81 525	.00 503	.82 027	18
43	.18 055	.99 495	.18 560	.81 440	.00 505	.81 945	17
44	.18 137	.99 494	.18 644	.81 356	.00 506	.81 863	16
45	9.18 220	9.99 492	9.18 728	0.81 272	0.00 508	0.81 780	**15**
46	.18 302	.99 490	.18 812	.81 188	.00 510	.81 698	14
47	.18 383	.99 488	.18 896	.81 104	.00 512	.81 617	13
48	.18 465	.99 486	.18 979	.81 021	.00 514	.81 535	12
49	.18 547	.99 484	.19 063	.80 937	.00 516	.81 453	11
50	9.18 628	9.99 482	9.19 146	0.80 854	0.00 518	0.81 372	**10**
51	.18 709	.99 480	.19 229	.80 771	.00 520	.81 291	9
52	.18 790	.99 478	.19 312	.80 688	.00 522	.81 210	8
53	.18 871	.99 476	.19 395	.80 605	.00 524	.81 129	7
54	.18 952	.99 474	.19 478	.80 522	.00 526	.81 048	6
55	9.19 033	9.99 472	9.19 561	0.80 439	0.00 528	0.80 967	**5**
56	.19 113	.99 470	.19 643	.80 357	.00 530	.80 887	4
57	.19 193	.99 468	.19 725	.80 275	.00 532	.80 807	3
58	.19 273	.99 466	.19 807	.80 193	.00 534	.80 727	2
59	.19 353	.99 464	.19 889	.80 111	.00 536	.80 647	1
60	9.19 433	9.99 462	9.19 971	0.80 029	0.00 538	0.80 567	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

98° (278°) (261°) 81°

9° (189°) (350°) **170°**

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.19 433	9.99 462	9.19 971	0.80 029	0.00 538	0.80 567	**60**
1	.19 513	.99 460	.20 053	.79 947	.00 540	.80 487	59
2	.19 592	.99 458	.20 134	.79 866	.00 542	.80 408	58
3	.19 672	.99 456	.20 216	.79 784	.00 544	.80 328	57
4	.19 751	.99 454	.20 297	.79 703	.00 546	.80 249	56
5	9.19 830	9.99 452	9.20 378	0.79 622	0.00 548	0.80 170	**55**
6	.19 909	.99 450	.20 459	.79 541	.00 550	.80 091	54
7	.19 988	.99 448	.20 540	.79 460	.00 552	.80 012	53
8	.20 067	.99 446	.20 621	.79 379	.00 554	.79 933	52
9	.20 145	.99 444	.20 701	.79 299	.00 556	.79 855	51
10	9.20 223	9.99 442	9.20 782	0.79 218	0.00 558	0.79 777	**50**
11	.20 302	.99 440	.20 862	.79 138	.00 560	.79 698	49
12	.20 380	.99 438	.20 942	.79 058	.00 562	.79 620	48
13	.20 458	.99 436	.21 022	.78 978	.00 564	.79 542	47
14	.20 535	.99 434	.21 102	.78 898	.00 566	.79 465	46
15	9.20 613	9.99 432	9.21 182	0.78 818	0.00 568	0.79 387	**45**
16	.20 691	.99 429	.21 261	.78 739	.00 571	.79 309	44
17	.20 768	.99 427	.21 341	.78 659	.00 573	.79 232	43
18	.20 845	.99 425	.21 420	.78 580	.00 575	.79 155	42
19	.20 922	.99 423	.21 499	.78 501	.00 577	.79 078	41
20	9.20 999	9.99 421	9.21 578	0.78 422	0.00 579	0.79 001	**40**
21	.21 076	.99 419	.21 657	.78 343	.00 581	.78 924	39
22	.21 153	.99 417	.21 736	.78 264	.00 583	.78 847	38
23	.21 229	.99 415	.21 814	.78 186	.00 585	.78 771	37
24	.21 306	.99 413	.21 893	.78 107	.00 587	.78 694	36
25	9.21 382	9.99 411	9.21 971	0.78 029	0.00 589	0.78 618	**35**
26	.21 458	.99 409	.22 049	.77 951	.00 591	.78 542	34
27	.21 534	.99 407	.22 127	.77 873	.00 593	.78 466	33
28	.21 610	.99 404	.22 205	.77 795	.00 596	.78 390	32
29	.21 685	.99 402	.22 283	.77 717	.00 598	.78 315	31
30	9.21 761	9.99 400	9.22 361	0.77 639	0.00 600	0.78 239	**30**
31	.21 836	.99 398	.22 438	.77 562	.00 602	.78 164	29
32	.21 912	.99 396	.22 516	.77 484	.00 604	.78 088	28
33	.21 987	.99 394	.22 593	.77 407	.00 606	.78 013	27
34	.22 062	.99 392	.22 670	.77 330	.00 608	.77 938	26
35	9.22 137	9.99 390	9.22 747	0.77 253	0.00 610	0.77 863	**25**
36	.22 211	.99 388	.22 824	.77 176	.00 612	.77 789	24
37	.22 286	.99 385	.22 901	.77 099	.00 615	.77 714	23
38	.22 361	.99 383	.22 977	.77 023	.00 617	.77 639	22
39	.22 435	.99 381	.23 054	.76 946	.00 619	.77 565	21
40	9.22 509	9.99 379	9.23 130	0.76 870	0.00 621	0.77 491	**20**
41	.22 583	.99 377	.23 206	.76 794	.00 623	.77 417	19
42	.22 657	.99 375	.23 283	.76 717	.00 625	.77 343	18
43	.22 731	.99 372	.23 359	.76 641	.00 628	.77 269	17
44	.22 805	.99 370	.23 435	.76 565	.00 630	.77 195	16
45	9.22 878	9.99 368	9.23 510	0.76 490	0.00 632	0.77 122	**15**
46	.22 952	.99 366	.23 586	.76 414	.00 634	.77 048	14
47	.23 025	.99 364	.23 661	.76 339	.00 636	.76 975	13
48	.23 098	.99 362	.23 737	.76 263	.00 638	.76 902	12
49	.23 171	.99 359	.23 812	.76 188	.00 641	.76 829	11
50	9.23 244	9.99 357	9.23 887	0.76 113	0.00 643	0.76 756	**10**
51	.23 317	.99 355	.23 962	.76 038	.00 645	.76 683	9
52	.23 390	.99 353	.24 037	.75 963	.00 647	.76 610	8
53	.23 462	.99 351	.24 112	.75 888	.00 649	.76 538	7
54	.23 535	.99 348	.24 186	.75 814	.00 652	.76 465	6
55	9.23 607	9.99 346	9.24 261	0.75 739	0.00 654	0.76 393	**5**
56	.23 679	.99 344	.24 335	.75 665	.00 656	.76 321	4
57	.23 752	.99 342	.24 410	.75 590	.00 658	.76 248	3
58	.23 823	.99 340	.24 484	.75 516	.00 660	.76 177	2
59	.23 895	.99 337	.24 558	.75 442	.00 663	.76 105	1
60	9.23 967	9.99 335	9.24 632	0.75 368	0.00 665	0.76 033	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

99° (279°) (260°) **80°**

10° (190°) (349°) 169°

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.23 967	9.99 335	9.24 632	0.75 368	0.00 665	0.76 033	**60**
1	.24 039	.99 333	.24 706	.75 294	.00 667	.75 961	59
2	.24 110	.99 331	.24 779	.75 221	.00 669	.75 890	58
3	.24 181	.99 328	.24 853	.75 147	.00 672	.75 819	57
4	.24 253	.99 326	.24 926	.75 074	.00 674	.75 747	56
5	9.24 324	9.99 324	9.25 000	0.75 000	0.00 676	0.75 676	**55**
6	.24 395	.99 322	.25 073	.74 927	.00 678	.75 605	54
7	.24 466	.99 319	.25 146	.74 854	.00 681	.75 534	53
8	.24 536	.99 317	.25 219	.74 781	.00 683	.75 464	52
9	.24 607	.99 315	.25 292	.74 708	.00 685	.75 393	51
10	9.24 677	9.99 313	9.25 365	0.74 635	0.00 687	0.75 323	**50**
11	.24 748	.99 310	.25 437	.74 563	.00 690	.75 252	49
12	.24 818	.99 308	.25 510	.74 490	.00 692	.75 182	48
13	.24 888	.99 306	.25 582	.74 418	.00 694	.75 112	47
14	.24 958	.99 304	.25 655	.74 345	.00 696	.75 042	46
15	9.25 028	9.99 301	9.25 727	0.74 273	0.00 699	0.74 972	**45**
16	.25 098	.99 299	.25 799	.74 201	.00 701	.74 902	44
17	.25 168	.99 297	.25 871	.74 129	.00 703	.74 832	43
18	.25 237	.99 294	.25 943	.74 057	.00 706	.74 763	42
19	.25 307	.99 292	.26 015	.73 985	.00 708	.74 693	41
20	9.25 376	9.99 290	9.26 086	0.73 914	0.00 710	0.74 624	**40**
21	.25 445	.99 288	.26 158	.73 842	.00 712	.74 555	39
22	.25 514	.99 285	.26 229	.73 771	.00 715	.74 486	38
23	.25 583	.99 283	.26 301	.73 699	.00 717	.74 417	37
24	.25 652	.99 281	.26 372	.73 628	.00 719	.74 348	36
25	9.25 721	9.99 278	9.26 443	0.73 557	0.00 722	0.74 279	**35**
26	.25 790	.99 276	.26 514	.73 486	.00 724	.74 210	34
27	.25 858	.99 274	.26 585	.73 415	.00 726	.74 142	33
28	.25 927	.99 271	.26 655	.73 345	.00 729	.74 073	32
29	.25 995	.99 269	.26 726	.73 274	.00 731	.74 005	31
30	9.26 063	9.99 267	9.26 797	0.73 203	0.00 733	0.73 937	**30**
31	.26 131	.99 264	.26 867	.73 133	.00 736	.73 869	29
32	.26 199	.99 262	.26 937	.73 063	.00 738	.73 801	28
33	.26 267	.99 260	.27 008	.72 992	.00 740	.73 733	27
34	.26 335	.99 257	.27 078	.72 922	.00 743	.73 665	26
35	9.26 403	9.99 255	9.27 148	0.72 852	0.00 745	0.73 597	**25**
36	.26 470	.99 252	.27 218	.72 782	.00 748	.73 530	24
37	.26 538	.99 250	.27 288	.72 712	.00 750	.73 462	23
38	.26 605	.99 248	.27 357	.72 643	.00 752	.73 395	22
39	.26 672	.99 245	.27 427	.72 573	.00 755	.73 328	21
40	9.26 739	9.99 243	9.27 496	0.72 504	0.00 757	0.73 261	**20**
41	.26 806	.99 241	.27 566	.72 434	.00 759	.73 194	19
42	.26 873	.99 238	.27 635	.72 365	.00 762	.73 127	18
43	.26 940	.99 236	.27 704	.72 296	.00 764	.73 060	17
44	.27 007	.99 233	.27 773	.72 227	.00 767	.72 993	16
45	9.27 073	9.99 231	9.27 842	0.72 158	0.00 769	0.72 927	**15**
46	.27 140	.99 229	.27 911	.72 089	.00 771	.72 860	14
47	.27 206	.99 226	.27 980	.72 020	.00 774	.72 794	13
48	.27 273	.99 224	.28 049	.71 951	.00 776	.72 727	12
49	.27 339	.99 221	.28 117	.71 883	.00 779	.72 661	11
50	9.27 405	9.99 219	9.28 186	0.71 814	0.00 781	0.72 595	**10**
51	.27 471	.99 217	.28 254	.71 746	.00 783	.72 529	9
52	.27 537	.99 214	.28 323	.71 677	.00 786	.72 463	8
53	.27 602	.99 212	.28 391	.71 609	.00 788	.72 398	7
54	.27 668	.99 209	.28 459	.71 541	.00 791	.72 332	6
55	9.27 734	9.99 207	9.28 527	0.71 473	0.00 793	0.72 266	**5**
56	.27 799	.99 204	.28 595	.71 405	.00 796	.72 201	4
57	.27 864	.99 202	.28 662	.71 338	.00 798	.72 136	3
58	.27 930	.99 200	.28 730	.71 270	.00 800	.72 070	2
59	.27 995	.99 197	.28 798	.71 202	.00 803	.72 005	1
60	9.28 060	9.99 195	9.28 865	0.71 135	0.00 805	0.71 940	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

100° (280°) (259°) 79°

11° (191°) (348°) 168°

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.28 060	9.99 195	9.28 865	0.71 135	0.00 805	0.71 940	**60**
1	.28 125	.99 192	.28 933	.71 067	.00 808	.71 875	59
2	.28 190	.99 190	.29 000	.71 000	.00 810	.71 810	58
3	.28 254	.99 187	.29 067	.70 933	.00 813	.71 746	57
4	.28 319	.99 185	.29 134	.70 866	.00 815	.71 681	56
5	9.28 384	9.99 182	9.29 201	0.70 799	0.00 818	0.71 616	**55**
6	.28 448	.99 180	.29 268	.70 732	.00 820	.71 552	54
7	.28 512	.99 177	.29 335	.70 665	.00 823	.71 488	53
8	.28 577	.99 175	.29 402	.70 598	.00 825	.71 423	52
9	.28 641	.99 172	.29 468	.70 532	.00 828	.71 359	51
10	9.28 705	9.99 170	9.29 535	0.70 465	0.00 830	0.71 295	**50**
11	.28 769	.99 167	.29 601	.70 399	.00 833	.71 231	49
12	.28 833	.99 165	.29 668	.70 332	.00 835	.71 167	48
13	.28 896	.99 162	.29 734	.70 266	.00 838	.71 104	47
14	.28 960	.99 160	.29 800	.70 200	.00 840	.71 040	46
15	9.29 024	9.99 157	9.29 866	0.70 134	0.00 843	0.70 976	**45**
16	.29 087	.99 155	.29 932	.70 068	.00 845	.70 913	44
17	.29 150	.99 152	.29 998	.70 002	.00 848	.70 850	43
18	.29 214	.99 150	.30 064	.69 936	.00 850	.70 786	42
19	.29 277	.99 147	.30 130	.69 870	.00 853	.70 723	41
20	9.29 340	9.99 145	9.30 195	0.69 805	0.00 855	0.70 660	**40**
21	.29 403	.99 142	.30 261	.69 739	.00 858	.70 597	39
22	.29 466	.99 140	.30 326	.69 674	.00 860	.70 534	38
23	.29 529	.99 137	.30 391	.69 609	.00 863	.70 471	37
24	.29 591	.99 135	.30 457	.69 543	.00 865	.70 409	36
25	9.29 654	9.99 132	9.30 522	0.69 478	0.00 868	0.70 346	**35**
26	.29 716	.99 130	.30 587	.69 413	.00 870	.70 284	34
27	.29 779	.99 127	.30 652	.69 348	.00 873	.70 221	33
28	.29 841	.99 124	.30 717	.69 283	.00 876	.70 159	32
29	.29 903	.99 122	.30 782	.69 218	.00 878	.70 097	31
30	9.29 966	9.99 119	9.30 846	0.69 154	0.00 881	0.70 034	**30**
31	.30 028	.99 117	.30 911	.69 089	.00 883	.69 972	29
32	.30 090	.99 114	.30 975	.69 025	.00 886	.69 910	28
33	.30 151	.99 112	.31 040	.68 960	.00 888	.69 849	27
34	.30 213	.99 109	.31 104	.68 896	.00 891	.69 787	26
35	9.30 275	9.99 106	9.31 168	0.68 832	0.00 894	0.69 725	**25**
36	.30 336	.99 104	.31 233	.68 767	.00 896	.69 664	24
37	.30 398	.99 101	.31 297	.68 703	.00 899	.69 602	23
38	.30 459	.99 099	.31 361	.68 639	.00 901	.69 541	22
39	.30 521	.99 096	.31 425	.68 575	.00 904	.69 479	21
40	9.30 582	9.99 093	9.31 489	0.68 511	0.00 907	0.69 418	**20**
41	.30 643	.99 091	.31 552	.68 448	.00 909	.69 357	19
42	.30 704	.99 088	.31 616	.68 384	.00 912	.69 296	18
43	.30 765	.99 086	.31 679	.68 321	.00 914	.69 235	17
44	.30 826	.99 083	.31 743	.68 257	.00 917	.69 174	16
45	9.30 887	9.99 080	9.31 806	0.68 194	0.00 920	0.69 113	**15**
46	.30 947	.99 078	.31 870	.68 130	.00 922	.69 053	14
47	.31 008	.99 075	.31 933	.68 067	.00 925	.68 992	13
48	.31 068	.99 072	.31 996	.68 004	.00 928	.68 932	12
49	.31 129	.99 070	.32 059	.67 941	.00 930	.68 871	11
50	9.31 189	9.99 067	9.32 122	0.67 878	0.00 933	0.68 811	**10**
51	.31 250	.99 064	.32 185	.67 815	.00 936	.68 750	9
52	.31 310	.99 062	.32 248	.67 752	.00 938	.68 690	8
53	.31 370	.99 059	.32 311	.67 689	.00 941	.68 630	7
54	.31 430	.99 056	.32 373	.67 627	.00 944	.68 570	6
55	9.31 490	9.99 054	9.32 436	0.67 564	0.00 946	0.68 510	**5**
56	.31 549	.99 051	.32 498	.67 502	.00 949	.68 451	4
57	.31 609	.99 048	.32 561	.67 439	.00 952	.68 391	3
58	.31 669	.99 046	.32 623	.67 377	.00 954	.68 331	2
59	.31 728	.99 043	.32 685	.67 315	.00 957	.68 272	1
60	9.31 788	9.99 040	9.32 747	0.67 253	0.00 960	0.68 212	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

101° (281°) (258°) 78°

12° (192°) (347°) **167°**

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.31 788	9.99 040	9.32 747	0.67 253	0.00 960	0.68 212	**60**
1	.31 847	.99 038	.32 810	.67 190	.00 962	.68 153	59
2	.31 907	.99 035	.32 872	.67 128	.00 965	.68 093	58
3	.31 966	.99 032	.32 933	.67 067	.00 968	.68 034	57
4	.32 025	.99 030	.32 995	.67 005	.00 970	.67 975	56
5	9.32 084	9.99 027	9.33 057	0.66 943	0.00 973	0.67 916	**55**
6	.32 143	.99 024	.33 119	.66 881	.00 976	.67 857	54
7	.32 202	.99 022	.33 180	.66 820	.00 978	.67 798	53
8	.32 261	.99 019	.33 242	.66 758	.00 981	.67 739	52
9	.32 319	.99 016	.33 303	.66 697	.00 984	.67 681	51
10	9.32 378	9.99 013	9.33 365	0.66 635	0.00 987	0.67 622	**50**
11	.32 437	.99 011	.33 426	.66 574	.00 989	.67 563	49
12	.32 495	.99 008	.33 487	.66 513	.00 992	.67 505	48
13	.32 553	.99 005	.33 548	.66 452	.00 995	.67 447	47
14	.32 612	.99 002	.33 609	.66 391	.00 998	.67 388	46
15	9.32 670	9.99 000	9.33 670	0.66 330	0.01 000	0.67 330	**45**
16	.32 728	.98 997	.33 731	.66 269	.01 003	.67 272	44
17	.32 786	.98 994	.33 792	.66 208	.01 006	.67 214	43
18	.32 844	.98 991	.33 853	.66 147	.01 009	.67 156	42
19	.32 902	.98 989	.33 913	.66 087	.01 011	.67 098	41
20	9.32 960	9.98 986	9.33 974	0.66 026	0.01 014	0.67 040	**40**
21	.33 018	.98 983	.34 034	.65 966	.01 017	.66 982	39
22	.33 075	.98 980	.34 095	.65 905	.01 020	.66 925	38
23	.33 133	.98 978	.34 155	.65 845	.01 022	.66 867	37
24	.33 190	.98 975	.34 215	.65 785	.01 025	.66 810	36
25	9.33 248	9.98 972	9.34 276	0.65 724	0.01 028	0.66 752	**35**
26	.33 305	.98 969	.34 336	.65 664	.01 031	.66 695	34
27	.33 362	.98 967	.34 396	.65 604	.01 033	.66 638	33
28	.33 420	.98 964	.34 456	.65 544	.01 036	.66 580	32
29	.33 477	.98 961	.34 516	.65 484	.01 039	.66 523	31
30	9.33 534	9.98 958	9.34 576	0.65 424	0.01 042	0.66 466	**30**
31	.33 591	.98 955	.34 635	.65 365	.01 045	.66 409	29
32	.33 647	.98 953	.34 695	.65 305	.01 047	.66 353	28
33	.33 704	.98 950	.34 755	.65 245	.01 050	.66 296	27
34	.33 761	.98 947	.34 814	.65 186	.01 053	.66 239	26
35	9.33 818	9.98 944	9.34 874	0.65 126	0.01 056	0.66 182	**25**
36	.33 874	.98 941	.34 933	.65 067	.01 059	.66 126	24
37	.33 931	.98 938	.34 992	.65 008	.01 062	.66 069	23
38	.33 987	.98 936	.35 051	.64 949	.01 064	.66 013	22
39	.34 043	.98 933	.35 111	.64 889	.01 067	.65 957	21
40	9.34 100	9.98 930	9.35 170	0.64 830	0.01 070	0.65 900	**20**
41	.34 156	.98 927	.35 229	.64 771	.01 073	.65 844	19
42	.34 212	.98 924	.35 288	.64 712	.01 076	.65 788	18
43	.34 268	.98 921	.35 347	.64 653	.01 079	.65 732	17
44	.34 324	.98 919	.35 405	.64 595	.01 081	.65 676	16
45	9.34 380	9.98 916	9.35 464	0.64 536	0.01 084	0.65 620	**15**
46	.34 436	.98 913	.35 523	.64 477	.01 087	.65 564	14
47	.34 491	.98 910	.35 581	.64 419	.01 090	.65 509	13
48	.34 547	.98 907	.35 640	.64 360	.01 093	.65 453	12
49	.34 602	.98 904	.35 698	.64 302	.01 096	.65 398	11
50	9.34 658	9.98 901	9.35 757	0.64 243	0.01 099	0.65 342	**10**
51	.34 713	.98 898	.35 815	.64 185	.01 102	.65 287	9
52	.34 769	.98 896	.35 873	.64 127	.01 104	.65 231	8
53	.34 824	.98 893	.35 931	.64 069	.01 107	.65 176	7
54	.34 879	.98 890	.35 989	.64 011	.01 110	.65 121	6
55	9.34 934	9.98 887	9.36 047	0.63 953	0.01 113	0.65 066	**5**
56	.34 989	.98 884	.36 105	.63 895	.01 116	.65 011	4
57	.35 044	.98 881	.36 163	.63 837	.01 119	.64 956	3
58	.35 099	.98 878	.36 221	.63 779	.01 122	.64 901	2
59	.35 154	.98 875	.36 279	.63 721	.01 125	.64 846	1
60	9.35 209	9.98 872	9.36 336	0.63 664	0.01 128	0.64 791	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

102° (282°) (257°) **77°**

13° (193°) (346°) **166°**

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.35 209	9.98 872	9.36 336	0.63 664	0.01 128	0.64 791	**60**
1	.35 263	.98 869	.36 394	.63 606	.01 131	.64 737	59
2	.35 318	.98 867	.36 452	.63 548	.01 133	.64 682	58
3	.35 373	.98 864	.36 509	.63 491	.01 136	.64 627	57
4	.35 427	.98 861	.36 566	.63 434	.01 139	.64 573	56
5	9.35 481	9.98 858	9.36 624	0.63 376	0.01 142	0.64 519	**55**
6	.35 536	.98 855	.36 681	.63 319	.01 145	.64 464	54
7	.35 590	.98 852	.36 738	.63 262	.01 148	.64 410	53
8	.35 644	.98 849	.36 795	.63 205	.01 151	.64 356	52
9	.35 698	.98 846	.36 852	.63 148	.01 154	.64 302	51
10	9.35 752	9.98 843	9.36 909	0.63 091	0.01 157	0.64 248	**50**
11	.35 806	.98 840	.36 966	.63 034	.01 160	.64 194	49
12	.35 860	.98 837	.37 023	.62 977	.01 163	.64 140	48
13	.35 914	.98 834	.37 080	.62 920	.01 166	.64 086	47
14	.35 968	.98 831	.37 137	.62 863	.01 169	.64 032	46
15	9.36 022	9.98 828	9.37 193	0.62 807	0.01 172	0.63 978	**45**
16	.36 075	.98 825	.37 250	.62 750	.01 175	.63 925	44
17	.36 129	.98 822	.37 306	.62 694	.01 178	.63 871	43
18	.36 182	.98 819	.37 363	.62 637	.01 181	.63 818	42
19	.36 236	.98 816	.37 419	.62 581	.01 184	.63 764	41
20	9.36 289	9.98 813	9.37 476	0.62 524	0.01 187	0.63 711	**40**
21	.36 342	.98 810	.37 532	.62 468	.01 190	.63 658	39
22	.36 395	.98 807	.37 588	.62 412	.01 193	.63 605	38
23	.36 449	.98 804	.37 644	.62 356	.01 196	.63 551	37
24	.36 502	.98 801	.37 700	.62 300	.01 199	.63 498	36
25	9.36 555	9.98 798	9.37 756	0.62 244	0.01 202	0.63 445	**35**
26	.36 608	.98 795	.37 812	.62 188	.01 205	.63 392	34
27	.36 660	.98 792	.37 868	.62 132	.01 208	.63 340	33
28	.36 713	.98 789	.37 924	.62 076	.01 211	.63 287	32
29	.36 766	.98 786	.37 980	.62 020	.01 214	.63 234	31
30	9.36 819	9.98 783	9.38 035	0.61 965	0.01 217	0.63 181	**30**
31	.36 871	.98 780	.38 091	.61 909	.01 220	.63 129	29
32	.36 924	.98 777	.38 147	.61 853	.01 223	.63 076	28
33	.36 976	.98 774	.38 202	.61 798	.01 226	.63 024	27
34	.37 028	.98 771	.38 257	.61 743	.01 229	.62 972	26
35	9.37 081	9.98 768	9.38 313	0.61 687	0.01 232	0.62 919	**25**
36	.37 133	.98 765	.38 368	.61 632	.01 235	.62 867	24
37	.37 185	.98 762	.38 423	.61 577	.01 238	.62 815	23
38	.37 237	.98 759	.38 479	.61 521	.01 241	.62 763	22
39	.37 289	.98 756	.38 534	.61 466	.01 244	.62 711	21
40	9.37 341	9.98 753	9.38 589	0.61 411	0.01 247	0.62 659	**20**
41	.37 393	.98 750	.38 644	.61 356	.01 250	.62 607	19
42	.37 445	.98 746	.38 699	.61 301	.01 254	.62 555	18
43	.37 497	.98 743	.38 754	.61 246	.01 257	.62 503	17
44	.37 549	.98 740	.38 808	.61 192	.01 260	.62 451	16
45	9.37 600	9.98 737	9.38 863	0.61 137	0.01 263	0.62 400	**15**
46	.37 652	.98 734	.38 918	.61 082	.01 266	.62 348	14
47	.37 703	.98 731	.38 972	.61 028	.01 269	.62 297	13
48	.37 755	.98 728	.39 027	.60 973	.01 272	.62 245	12
49	.37 806	.98 725	.39 082	.60 918	.01 275	.62 194	11
50	9.37 858	9.98 722	9.39 136	0.60 864	0.01 278	0.62 142	**10**
51	.37 909	.98 719	.39 190	.60 810	.01 281	.62 091	9
52	.37 960	.98 715	.39 245	.60 755	.01 285	.62 040	8
53	.38 011	.98 712	.39 299	.60 701	.01 288	.61 989	7
54	.38 062	.98 709	.39 353	.60 647	.01 291	.61 938	6
55	9.38 113	9.98 706	9.39 407	0.60 593	0.01 294	0.61 887	**5**
56	.38 164	.98 703	.39 461	.60 539	.01 297	.61 836	4
57	.38 215	.98 700	.39 515	.60 485	.01 300	.61 785	3
58	.38 266	.98 697	.39 569	.60 431	.01 303	.61 734	2
59	.38 317	.98 694	.39 623	.60 377	.01 306	.61 683	1
60	9.38 368	9.98 690	9.39 677	0.60 323	0.01 310	0.61 632	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

103° (283°) (256°) **76°**

14° (194°) (345°) **165°**

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.38 368	9.98 690	9.39 677	0.60 323	0.01 310	0.61 632	**60**
1	.38 418	.98 687	.39 731	.60 269	.01 313	.61 582	59
2	.38 469	.98 684	.39 785	.60 215	.01 316	.61 531	58
3	.38 519	.98 681	.39 838	.60 162	.01 319	.61 481	57
4	.38 570	.98 678	.39 892	.60 108	.01 322	.61 430	56
5	9.38 620	9.98 675	9.39 945	0.60 055	0.01 325	0.61 380	**55**
6	.38 670	.98 671	.39 999	.60 001	.01 329	.61 330	54
7	.38 721	.98 668	.40 052	.59 948	.01 332	.61 279	53
8	.38 771	.98 665	.40 106	.59 894	.01 335	.61 229	52
9	.38 821	.98 662	.40 159	.59 841	.01 338	.61 179	51
10	9.38 871	9.98 659	9.40 212	0.59 788	0.01 341	0.61 129	**50**
11	.38 921	.98 656	.40 266	.59 734	.01 344	.61 079	49
12	.38 971	.98 652	.40 319	.59 681	.01 348	.61 029	48
13	.39 021	.98 649	.40 372	.59 628	.01 351	.60 979	47
14	.39 071	.98 646	.40 425	.59 575	.01 354	.60 929	46
15	9.39 121	9.98 643	9.40 478	0.59 522	0.01 357	0.60 879	**45**
16	.39 170	.98 640	.40 531	.59 469	.01 360	.60 830	44
17	.39 220	.98 636	.40 584	.59 416	.01 364	.60 780	43
18	.39 270	.98 633	.40 636	.59 364	.01 367	.60 730	42
19	.39 319	.98 630	.40 689	.59 311	.01 370	.60 681	41
20	9.39 369	9.98 627	9.40 742	0.59 258	0.01 373	0.60 631	**40**
21	.39 418	.98 623	.40 795	.59 205	.01 377	.60 582	39
22	.39 467	.98 620	.40 847	.59 153	.01 380	.60 533	38
23	.39 517	.98 617	.40 900	.59 100	.01 383	.60 483	37
24	.39 566	.98 614	.40 952	.59 048	.01 386	.60 434	36
25	9.39 615	9.98 610	9.41 005	0.58 995	0.01 390	0.60 385	**35**
26	.39 664	.98 607	.41 057	.58 943	.01 393	.60 336	34
27	.39 713	.98 604	.41 109	.58 891	.01 396	.60 287	33
28	.39 762	.98 601	.41 161	.58 839	.01 399	.60 238	32
29	.39 811	.98 597	.41 214	.58 786	.01 403	.60 189	31
30	9.39 860	9.98 594	9.41 266	0.58 734	0.01 406	0.60 140	**30**
31	.39 909	.98 591	.41 318	.58 682	.01 409	.60 091	29
32	.39 958	.98 588	.41 370	.58 630	.01 412	.60 042	28
33	.40 006	.98 584	.41 422	.58 578	.01 416	.59 994	27
34	.40 055	.98 581	.41 474	.58 526	.01 419	.59 945	26
35	9.40 103	9.98 578	9.41 526	0.58 474	0.01 422	0.59 897	**25**
36	.40 152	.98 574	.41 578	.58 422	.01 426	.59 848	24
37	.40 200	.98 571	.41 629	.58 371	.01 429	.59 800	23
38	.40 249	.98 568	.41 681	.58 319	.01 432	.59 751	22
39	.40 297	.98 565	.41 733	.58 267	.01 435	.59 703	21
40	9.40 346	9.98 561	9.41 784	0.58 216	0.01 439	0.59 654	**20**
41	.40 394	.98 558	.41 836	.58 164	.01 442	.59 606	19
42	.40 442	.98 555	.41 887	.58 113	.01 445	.59 558	18
43	.40 490	.98 551	.41 939	.58 061	.01 449	.59 510	17
44	.40 538	.98 548	.41 990	.58 010	.01 452	.59 462	16
45	9.40 586	9.98 545	9.42 041	0.57 959	0.01 455	0.59 414	**15**
46	.40 634	.98 541	.42 093	.57 907	.01 459	.59 366	14
47	.40 682	.98 538	.42 144	.57 856	.01 462	.59 318	13
48	.40 730	.98 535	.42 195	.57 805	.01 465	.59 270	12
49	.40 778	.98 531	.42 246	.57 754	.01 469	.59 222	11
50	9.40 825	9.98 528	9.42 297	0.57 703	0.01 472	0.59 175	**10**
51	.40 873	.98 525	.42 348	.57 652	.01 475	.59 127	9
52	.40 921	.98 521	.42 399	.57 601	.01 479	.59 079	8
53	.40 968	.98 518	.42 450	.57 550	.01 482	.59 032	7
54	.41 016	.98 515	.42 501	.57 499	.01 485	.58 984	6
55	9.41 063	9.98 511	9.42 552	0.57 448	0.01 489	0.58 937	**5**
56	.41 111	.98 508	.42 603	.57 397	.01 492	.58 889	4
57	.41 158	.98 505	.42 653	.57 347	.01 495	.58 842	3
58	.41 205	.98 501	.42 704	.57 296	.01 499	.58 795	2
59	.41 252	.98 498	.42 755	.57 245	.01 502	.58 748	1
60	9.41 300	9.98 494	9.42 805	0.57 195	0.01 506	0.58 700	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

104° (284°) (255°) **75°**

15° (195°) (344°) **164°**

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.41 300	9.98 494	9.42 805	0.57 195	0.01 506	0.58 700	**60**
1	.41 347	.98 491	.42 856	.57 144	.01 509	.58 653	59
2	.41 394	.98 488	.42 906	.57 094	.01 512	.58 606	58
3	.41 441	.98 484	.42 957	.57 043	.01 516	.58 559	57
4	.41 488	.98 481	.43 007	.56 993	.01 519	.58 512	56
5	9.41 535	9.98 477	9.43 057	0.56 943	0.01 523	0.58 465	**55**
6	.41 582	.98 474	.43 108	.56 892	.01 526	.58 418	54
7	.41 628	.98 471	.43 158	.56 842	.01 529	.58 372	53
8	.41 675	.98 467	.43 208	.56 792	.01 533	.58 325	52
9	.41 722	.98 464	.43 258	.56 742	.01 536	.58 278	51
10	9.41 768	9.98 460	9.43 308	0.56 692	0.01 540	0.58 232	**50**
11	.41 815	.98 457	.43 358	.56 642	.01 543	.58 185	49
12	.41 861	.98 453	.43 408	.56 592	.01 547	.58 139	48
13	.41 908	.98 450	.43 458	.56 542	.01 550	.58 092	47
14	.41 954	.98 447	.43 508	.56 492	.01 553	.58 046	46
15	9.42 001	9.98 443	9.43 558	0.56 442	0.01 557	0.57 999	**45**
16	.42 047	.98 440	.43 607	.56 393	.01 560	.57 953	44
17	.42 093	.98 436	.43 657	.56 343	.01 564	.57 907	43
18	.42 140	.98 433	.43 707	.56 293	.01 567	.57 860	42
19	.42 186	.98 429	.43 756	.56 244	.01 571	.57 814	41
20	9.42 232	9.98 426	9.43 806	0.56 194	0.01 574	0.57 768	**40**
21	.42 278	.98 422	.43 855	.56 145	.01 578	.57 722	39
22	.42 324	.98 419	.43 905	.56 095	.01 581	.57 676	38
23	.42 370	.98 415	.43 954	.56 046	.01 585	.57 630	37
24	.42 416	.98 412	.44 004	.55 996	.01 588	.57 584	36
25	9.42 461	9.98 409	9.44 053	0.55 947	0.01 591	0.57 539	**35**
26	.42 507	.98 405	.44 102	.55 898	.01 595	.57 493	34
27	.42 553	.98 402	.44 151	.55 849	.01 598	.57 447	33
28	.42 599	.98 398	.44 201	.55 799	.01 602	.57 401	32
29	.42 644	.98 395	.44 250	.55 750	.01 605	.57 356	31
30	9.42 690	9.98 391	9.44 299	0.55 701	0.01 609	0.57 310	**30**
31	.42 735	.98 388	.44 348	.55 652	.01 612	.57 265	29
32	.42 781	.98 384	.44 397	.55 603	.01 616	.57 219	28
33	.42 826	.98 381	.44 446	.55 554	.01 619	.57 174	27
34	.42 872	.98 377	.44 495	.55 505	.01 623	.57 128	26
35	9.42 917	9.98 373	9.44 544	0.55 456	0.01 627	0.57 083	**25**
36	.42 962	.98 370	.44 592	.55 408	.01 630	.57 038	24
37	.43 008	.98 366	.44 641	.55 359	.01 634	.56 992	23
38	.43 053	.98 363	.44 690	.55 310	.01 637	.56 947	22
39	.43 098	.98 359	.44 738	.55 262	.01 641	.56 902	21
40	9.43 143	9.98 356	9.44 787	0.55 213	0.01 644	0.56 857	**20**
41	.43 188	.98 352	.44 836	.55 164	.01 648	.56 812	19
42	.43 233	.98 349	.44 884	.55 116	.01 651	.56 767	18
43	.43 278	.98 345	.44 933	.55 067	.01 655	.56 722	17
44	.43 323	.98 342	.44 981	.55 019	.01 658	.56 677	16
45	9.43 367	9.98 338	9.45 029	0.54 971	0.01 662	0.56 633	**15**
46	.43 412	.98 334	.45 078	.54 922	.01 666	.56 588	14
47	.43 457	.98 331	.45 126	.54 874	.01 669	.56 543	13
48	.43 502	.98 327	.45 174	.54 826	.01 673	.56 498	12
49	.43 546	.98 324	.45 222	.54 778	.01 676	.56 454	11
50	9.43 591	9.98 320	9.45 271	0.54 729	0.01 680	0.56 409	**10**
51	.43 635	.98 317	.45 319	.54 681	.01 683	.56 365	9
52	.43 680	.98 313	.45 367	.54 633	.01 687	.56 320	8
53	.43 724	.98 309	.45 415	.54 585	.01 691	.56 276	7
54	.43 769	.98 306	.45 463	.54 537	.01 694	.56 231	6
55	9.43 813	9.98 302	9.45 511	0.54 489	0.01 698	0.56 187	**5**
56	.43 857	.98 299	.45 559	.54 441	.01 701	.56 143	4
57	.43 901	.98 295	.45 606	.54 394	.01 705	.56 099	3
58	.43 946	.98 291	.45 654	.54 346	.01 709	.56 054	2
59	.43 990	.98 288	.45 702	.54 298	.01 712	.56 010	1
60	9.44 034	9.98 284	9.45 750	0.54 250	0.01 716	0.55 966	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

105° (285°) (254°) **74°**

16° (196°) (343°) **163°**

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.44 034	9.98 284	9.45 750	0.54 250	0.01 716	0.55 966	**60**
1	.44 078	.98 281	.45 797	.54 203	.01 719	.55 922	59
2	.44 122	.98 277	.45 845	.54 155	.01 723	.55 878	58
3	.44 166	.98 273	.45 892	.54 108	.01 727	.55 834	57
4	.44 210	.98 270	.45 940	.54 060	.01 730	.55 790	56
5	9.44 253	9.98 266	9.45 987	0.54 013	0.01 734	0.55 747	**55**
6	.44 297	.98 262	.46 035	.53 965	.01 738	.55 703	54
7	.44 341	.98 259	.46 082	.53 918	.01 741	.55 659	53
8	.44 385	.98 255	.46 130	.53 870	.01 745	.55 615	52
9	.44 428	.98 251	.46 177	.53 823	.01 749	.55 572	51
10	9.44 472	9.98 248	9.46 224	0.53 776	0.01 752	0.55 528	**50**
11	.44 516	.98 244	.46 271	.53 729	.01 756	.55 484	49
12	.44 559	.98 240	.46 319	.53 681	.01 760	.55 441	48
13	.44 602	.98 237	.46 366	.53 634	.01 763	.55 398	47
14	.44 646	.98 233	.46 413	.53 587	.01 767	.55 354	46
15	9.44 689	9.98 229	9.46 460	0.53 540	0.01 771	0.55 311	**45**
16	.44 733	.98 226	.46 507	.53 493	.01 774	.55 267	44
17	.44 776	.98 222	.46 554	.53 446	.01 778	.55 224	43
18	.44 819	.98 218	.46 601	.53 399	.01 782	.55 181	42
19	.44 862	.98 215	.46 648	.53 352	.01 785	.55 138	41
20	9.44 905	9.98 211	9.46 694	0.53 306	0.01 789	0.55 095	**40**
21	.44 948	.98 207	.46 741	.53 259	.01 793	.55 052	39
22	.44 992	.98 204	.46 788	.53 212	.01 796	.55 008	38
23	.45 035	.98 200	.46 835	.53 165	.01 800	.54 965	37
24	.45 077	.98 196	.46 881	.53 119	.01 804	.54 923	36
25	9.45 120	9.98 192	9.46 928	0.53 072	0.01 808	0.54 880	**35**
26	.45 163	.98 189	.46 975	.53 025	.01 811	.54 837	34
27	.45 206	.98 185	.47 021	.52 979	.01 815	.54 794	33
28	.45 249	.98 181	.47 068	.52 932	.01 819	.54 751	32
29	.45 292	.98 177	.47 114	.52 886	.01 823	.54 708	31
30	9.45 334	9.98 174	9.47 160	0.52 840	0.01 826	0.54 666	**30**
31	.45 377	.98 170	.47 207	.52 793	.01 830	.54 623	29
32	.45 419	.98 166	.47 253	.52 747	.01 834	.54 581	28
33	.45 462	.98 162	.47 299	.52 701	.01 838	.54 538	27
34	.45 504	.98 159	.47 346	.52 654	.01 841	.54 496	26
35	9.45 547	9.98 155	9.47 392	0.52 608	0.01 845	0.54 453	**25**
36	.45 589	.98 151	.47 438	.52 562	.01 849	.54 411	24
37	.45 632	.98 147	.47 484	.52 516	.01 853	.54 368	23
38	.45 674	.98 144	.47 530	.52 470	.01 856	.54 326	22
39	.45 716	.98 140	.47 576	.52 424	.01 860	.54 284	21
40	9.45 758	9.98 136	9.47 622	0.52 378	0.01 864	0.54 242	**20**
41	.45 801	.98 132	.47 668	.52 332	.01 868	.54 199	19
42	.45 843	.98 129	.47 714	.52 286	.01 871	.54 157	18
43	.45 885	.98 125	.47 760	.52 240	.01 875	.54 115	17
44	.45 927	.98 121	.47 806	.52 194	.01 879	.54 073	16
45	9.45 969	9.98 117	9.47 852	0.52 148	0.01 883	0.54 031	**15**
46	.46 011	.98 113	.47 897	.52 103	.01 887	.53 989	14
47	.46 053	.98 110	.47 943	.52 057	.01 890	.53 947	13
48	.46 095	.98 106	.47 989	.52 011	.01 894	.53 905	12
49	.46 136	.98 102	.48 035	.51 965	.01 898	.53 864	11
50	9.46 178	9.98 098	9.48 080	0.51 920	0.01 902	0.53 822	**10**
51	.46 220	.98 094	.48 126	.51 874	.01 906	.53 780	9
52	.46 262	.98 090	.48 171	.51 829	.01 910	.53 738	8
53	.46 303	.98 087	.48 217	.51 783	.01 913	.53 697	7
54	.46 345	.98 083	.48 262	.51 738	.01 917	.53 655	6
55	9.46 386	9.98 079	9.48 307	0.51 693	0.01 921	0.53 614	**5**
56	.46 428	.98 075	.48 353	.51 647	.01 925	.53 572	4
57	.46 469	.98 071	.48 398	.51 602	.01 929	.53 531	3
58	.46 511	.98 067	.48 443	.51 557	.01 933	.53 489	2
59	.46 552	.98 063	.48 489	.51 511	.01 937	.53 448	1
60	9.46 594	9.98 060	9.48 534	0.51 466	0.01 940	0.53 406	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

106° (286°) (253°) **73°**

17° (197°) (342°) **162°**

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.46 594	9.98 060	9.48 534	0.51 466	0.01 940	0.53 406	**60**
1	.46 635	.98 056	.48 579	.51 421	.01 944	.53 365	59
2	.46 676	.98 052	.48 624	.51 376	.01 948	.53 324	58
3	.46 717	.98 048	.48 669	.51 331	.01 952	.53 283	57
4	.46 758	.98 044	.48 714	.51 286	.01 956	.53 242	56
5	9.46 800	9.98 040	9.48 759	0.51 241	0.01 960	0.53 200	**55**
6	.46 841	.98 036	.48 804	.51 196	.01 964	.53 159	54
7	.46 882	.98 032	.48 849	.51 151	.01 968	.53 118	53
8	.46 923	.98 029	.48 894	.51 106	.01 971	.53 077	52
9	.46 964	.98 025	.48 939	.51 061	.01 975	.53 036	51
10	9.47 005	9.98 021	9.48 984	0.51 016	0.01 979	0.52 995	**50**
11	.47 045	.98 017	.49 029	.50 971	.01 983	.52 955	49
12	.47 086	.98 013	.49 073	.50 927	.01 987	.52 914	48
13	.47 127	.98 009	.49 118	.50 882	.01 991	.52 873	47
14	.47 168	.98 005	.49 163	.50 837	.01 995	.52 832	46
15	9.47 209	9.98 001	9.49 207	0.50 793	0.01 999	0.52 791	**45**
16	.47 249	.97 997	.49 252	.50 748	.02 003	.52 751	44
17	.47 290	.97 993	.49 296	.50 704	.02 007	.52 710	43
18	.47 330	.97 989	.49 341	.50 659	.02 011	.52 670	42
19	.47 371	.97 986	.49 385	.50 615	.02 014	.52 629	41
20	9.47 411	9.97 982	9.49 430	0.50 570	0.02 018	0.52 589	**40**
21	.47 452	.97 978	.49 474	.50 526	.02 022	.52 548	39
22	.47 492	.97 974	.49 519	.50 481	.02 026	.52 508	38
23	.47 533	.97 970	.49 563	.50 437	.02 030	.52 467	37
24	.47 573	.97 966	.49 607	.50 393	.02 034	.52 427	36
25	9.47 613	9.97 962	9.49 652	0.50 348	0.02 038	0.52 387	**35**
26	.47 654	.97 958	.49 696	.50 304	.02 042	.52 346	34
27	.47 694	.97 954	.49 740	.50 260	.02 046	.52 306	33
28	.47 734	.97 950	.49 784	.50 216	.02 050	.52 266	32
29	.47 774	.97 946	.49 828	.50 172	.02 054	.52 226	31
30	9.47 814	9.97 942	9.49 872	0.50 128	0.02 058	0.52 186	**30**
31	.47 854	.97 938	.49 916	.50 084	.02 062	.52 146	29
32	.47 894	.97 934	.49 960	.50 040	.02 066	.52 106	28
33	.47 934	.97 930	.50 004	.49 996	.02 070	.52 066	27
34	.47 974	.97 926	.50 048	.49 952	.02 074	.52 026	26
35	9.48 014	9.97 922	9.50 092	0.49 908	0.02 078	0.51 986	**25**
36	.48 054	.97 918	.50 136	.49 864	.02 082	.51 946	24
37	.48 094	.97 914	.50 180	.49 820	.02 086	.51 906	23
38	.48 133	.97 910	.50 223	.49 777	.02 090	.51 867	22
39	.48 173	.97 906	.50 267	.49 733	.02 094	.51 827	21
40	9.48 213	9.97 902	9.50 311	0.49 689	0.02 098	0.51 787	**20**
41	.48 252	.97 898	.50 355	.49 645	.02 102	.51 748	19
42	.48 292	.97 894	.50 398	.49 602	.02 106	.51 708	18
43	.48 332	.97 890	.50 442	.49 558	.02 110	.51 668	17
44	.48 371	.97 886	.50 485	.49 515	.02 114	.51 629	16
45	9.48 411	9.97 882	9.50 529	0.49 471	0.02 118	0.51 589	**15**
46	.48 450	.97 878	.50 572	.49 428	.02 122	.51 550	14
47	.48 490	.97 874	.50 616	.49 384	.02 126	.51 510	13
48	.48 529	.97 870	.50 659	.49 341	.02 130	.51 471	12
49	.48 568	.97 866	.50 703	.49 297	.02 134	.51 432	11
50	9.48 607	9.97 861	9.50 746	0.49 254	0.02 139	0.51 393	**10**
51	.48 647	.97 857	.50 789	.49 211	.02 143	.51 353	9
52	.48 686	.97 853	.50 833	.49 167	.02 147	.51 314	8
53	.48 725	.97 849	.50 876	.49 124	.02 151	.51 275	7
54	.48 764	.97 845	.50 919	.49 081	.02 155	.51 236	6
55	9.48 803	9.97 841	9.50 962	0.49 038	0.02 159	0.51 197	**5**
56	.48 842	.97 837	.51 005	.48 995	.02 163	.51 158	4
57	.48 881	.97 833	.51 048	.48 952	.02 167	.51 119	3
58	.48 920	.97 829	.51 092	.48 908	.02 171	.51 080	2
59	.48 959	.97 825	.51 135	.48 865	.02 175	.51 041	1
60	9.48 998	9.97 821	9.51 178	0.48 822	0.02 179	0.51 002	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

107° (287°) (252°) **72°**

18° (198°) (341°) 161°

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.48 998	9.97 821	9.51 178	0.48 822	0.02 179	0.51 002	**60**
1	.49 037	.97 817	.51 221	.48 779	.02 183	.50 963	59
2	.49 076	.97 812	.51 264	.48 736	.02 188	.50 924	58
3	.49 115	.97 808	.51 306	.48 694	.02 192	.50 885	57
4	.49 153	.97 804	.51 349	.48 651	.02 196	.50 847	56
5	9.49 192	9.97 800	9.51 392	0.48 608	0.02 200	0.50 808	**55**
6	.49 231	.97 796	.51 435	.48 565	.02 204	.50 769	54
7	.49 269	.97 792	.51 478	.48 522	.02 208	.50 731	53
8	.49 308	.97 788	.51 520	.48 480	.02 212	.50 692	52
9	.49 347	.97 784	.51 563	.48 437	.02 216	.50 653	51
10	9.49 385	9.97 779	9.51 606	0.48 394	0.02 221	0.50 615	**50**
11	.49 424	.97 775	.51 648	.48 352	.02 225	.50 576	49
12	.49 462	.97 771	.51 691	.48 309	.02 229	.50 538	48
13	.49 500	.97 767	.51 734	.48 266	.02 233	.50 500	47
14	.49 539	.97 763	.51 776	.48 224	.02 237	.50 461	46
15	9.49 577	9.97 759	9.51 819	0.48 181	0.02 241	0.50 423	**45**
16	.49 615	.97 754	.51 861	.48 139	.02 246	.50 385	44
17	.49 654	.97 750	.51 903	.48 097	.02 250	.50 346	43
18	.49 692	.97 746	.51 946	.48 054	.02 254	.50 308	42
19	.49 730	.97 742	.51 988	.48 012	.02 258	.50 270	41
20	9.49 768	9.97 738	9.52 031	0.47 969	0.02 262	0.50 232	**40**
21	.49 806	.97 734	.52 073	.47 927	.02 266	.50 194	39
22	.49 844	.97 729	.52 115	.47 885	.02 271	.50 156	38
23	.49 882	.97 725	.52 157	.47 843	.02 275	.50 118	37
24	.49 920	.97 721	.52 200	.47 800	.02 279	.50 080	36
25	9.49 958	9.97 717	9.52 242	0.47 758	0.02 283	0.50 042	**35**
26	.49 996	.97 713	.52 284	.47 716	.02 287	.50 004	34
27	.50 034	.97 708	.52 326	.47 674	.02 292	.49 966	33
28	.50 072	.97 704	.52 368	.47 632	.02 296	.49 928	32
29	.50 110	.97 700	.52 410	.47 590	.02 300	.49 890	31
30	9.50 148	9.97 696	9.52 452	0.47 548	0.02 304	0.49 852	**30**
31	.50 185	.97 691	.52 494	.47 506	.02 309	.49 815	29
32	.50 223	.97 687	.52 536	.47 464	.02 313	.49 777	28
33	.50 261	.97 683	.52 578	.47 422	.02 317	.49 739	27
34	.50 298	.97 679	.52 620	.47 380	.02 321	.49 702	26
35	9.50 336	9.97 674	9.52 661	0.47 339	0.02 326	0.49 664	**25**
36	.50 374	.97 670	.52 703	.47 297	.02 330	.49 626	24
37	.50 411	.97 666	.52 745	.47 255	.02 334	.49 589	23
38	.50 449	.97 662	.52 787	.47 213	.02 338	.49 551	22
39	.50 486	.97 657	.52 829	.47 171	.02 343	.49 514	21
40	9.50 523	9.97 653	9.52 870	0.47 130	0.02 347	0.49 477	**20**
41	.50 561	.97 649	.52 912	.47 088	.02 351	.49 439	19
42	.50 598	.97 645	.52 953	.47 047	.02 355	.49 402	18
43	.50 635	.97 640	.52 995	.47 005	.02 360	.49 365	17
44	.50 673	.97 636	.53 037	.46 963	.02 364	.49 327	16
45	9.50 710	9.97 632	9.53 078	0.46 922	0.02 368	0.49 290	**15**
46	.50 747	.97 628	.53 120	.46 880	.02 372	.49 253	14
47	.50 784	.97 623	.53 161	.46 839	.02 377	.49 216	13
48	.50 821	.97 619	.53 202	.46 798	.02 381	.49 179	12
49	.50 858	.97 615	.53 244	.46 756	.02 385	.49 142	11
50	9.50 896	9.97 610	9.53 285	0.46 715	0.02 390	0.49 104	**10**
51	.50 933	.97 606	.53 327	.46 673	.02 394	.49 067	9
52	.50 970	.97 602	.53 368	.46 632	.02 398	.49 030	8
53	.51 007	.97 597	.53 409	.46 591	.02 403	.48 993	7
54	.51 043	.97 593	.53 450	.46 550	.02 407	.48 957	6
55	9.51 080	9.97 589	9.53 492	0.46 508	0.02 411	0.48 920	**5**
56	.51 117	.97 584	.53 533	.46 467	.02 416	.48 883	4
57	.51 154	.97 580	.53 574	.46 426	.02 420	.48 846	3
58	.51 191	.97 576	.53 615	.46 385	.02 424	.48 809	2
59	.51 227	.97 571	.53 656	.46 344	.02 429	.48 773	1
60	9.51 264	9.97 567	9.53 697	0.46 303	0.02 433	0.48 736	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

108° (288°) (251°) 71°

19° (199°) (340°) 160°

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.51 264	9.97 567	9.53 697	0.46 303	0.02 433	0.48 736	**60**
1	.51 301	.97 563	.53 738	.46 262	.02 437	.48 699	59
2	.51 338	.97 558	.53 779	.46 221	.02 442	.48 662	58
3	.51 374	.97 554	.53 820	.46 180	.02 446	.48 626	57
4	.51 411	.97 550	.53 861	.46 139	.02 450	.48 589	56
5	9.51 447	9.97 545	9.53 902	0.46 098	0.02 455	0.48 553	**55**
6	.51 484	.97 541	.53 943	.46 057	.02 459	.48 516	54
7	.51 520	.97 536	.53 984	.46 016	.02 464	.48 480	53
8	.51 557	.97 532	.54 025	.45 975	.02 468	.48 443	52
9	.51 593	.97 528	.54 065	.45 935	.02 472	.48 407	51
10	9.51 629	9.97 523	9.54 106	0.45 894	0.02 477	0.48 371	**50**
11	.51 666	.97 519	.54 147	.45 853	.02 481	.48 334	49
12	.51 702	.97 515	.54 187	.45 813	.02 485	.48 298	48
13	.51 738	.97 510	.54 228	.45 772	.02 490	.48 262	47
14	.51 774	.97 506	.54 269	.45 731	.02 494	.48 226	46
15	9.51 811	9.97 501	9.54 309	0.45 691	0.02 499	0.48 189	**45**
16	.51 847	.97 497	.54 350	.45 650	.02 503	.48 153	44
17	.51 883	.97 492	.54 390	.45 610	.02 508	.48 117	43
18	.51 919	.97 488	.54 431	.45 569	.02 512	.48 081	42
19	.51 955	.97 484	.54 471	.45 529	.02 516	.48 045	41
20	9.51 991	9.97 479	9.54 512	0.45 488	0.02 521	0.48 009	**40**
21	.52 027	.97 475	.54 552	.45 448	.02 525	.47 973	39
22	.52 063	.97 470	.54 593	.45 407	.02 530	.47 937	38
23	.52 099	.97 466	.54 633	.45 367	.02 534	.47 901	37
24	.52 135	.97 461	.54 673	.45 327	.02 539	.47 865	36
25	9.52 171	9.97 457	9.54 714	0.45 286	0.02 543	0.47 829	**35**
26	.52 207	.97 453	.54 754	.45 246	.02 547	.47 793	34
27	.52 242	.97 448	.54 794	.45 206	.02 552	.47 758	33
28	.52 278	.97 444	.54 835	.45 165	.02 556	.47 722	32
29	.52 314	.97 439	.54 875	.45 125	.02 561	.47 686	31
30	9.52 350	9.97 435	9.54 915	0.45 085	0.02 565	0.47 650	**30**
31	.52 385	.97 430	.54 955	.45 045	.02 570	.47 615	29
32	.52 421	.97 426	.54 995	.45 005	.02 574	.47 579	28
33	.52 456	.97 421	.55 035	.44 965	.02 579	.47 544	27
34	.52 492	.97 417	.55 075	.44 925	.02 583	.47 508	26
35	9.52 527	9.97 412	9.55 115	0.44 885	0.02 588	0.47 473	**25**
36	.52 563	.97 408	.55 155	.44 845	.02 592	.47 437	24
37	.52 598	.97 403	.55 195	.44 805	.02 597	.47 402	23
38	.52 634	.97 399	.55 235	.44 765	.02 601	.47 366	22
39	.52 669	.97 394	.55 275	.44 725	.02 606	.47 331	21
40	9.52 705	9.97 390	9.55 315	0.44 685	0.02 610	0.47 295	**20**
41	.52 740	.97 385	.55 355	.44 645	.02 615	.47 260	19
42	.52 775	.97 381	.55 395	.44 605	.02 619	.47 225	18
43	.52 811	.97 376	.55 434	.44 566	.02 624	.47 189	17
44	.52 846	.97 372	.55 474	.44 526	.02 628	.47 154	16
45	9.52 881	9.97 367	9.55 514	0.44 486	0.02 633	0.47 119	**15**
46	.52 916	.97 363	.55 554	.44 446	.02 637	.47 084	14
47	.52 951	.97 358	.55 593	.44 407	.02 642	.47 049	13
48	.52 986	.97 353	.55 633	.44 367	.02 647	.47 014	12
49	.53 021	.97 349	.55 673	.44 327	.02 651	.46 979	11
50	9.53 056	9.97 344	9.55 712	0.44 288	0.02 656	0.46 944	**10**
51	.53 092	.97 340	.55 752	.44 248	.02 660	.46 908	9
52	.53 126	.97 335	.55 791	.44 209	.02 665	.46 874	8
53	.53 161	.97 331	.55 831	.44 169	.02 669	.46 839	7
54	.53 196	.97 326	.55 870	.44 130	.02 674	.46 804	6
55	9.53 231	9.97 322	9.55 910	0.44 090	0.02 678	0.46 769	**5**
56	.53 266	.97 317	.55 949	.44 051	.02 683	.46 734	4
57	.53 301	.97 312	.55 989	.44 011	.02 688	.46 699	3
58	.53 336	.97 308	.56 028	.43 972	.02 692	.46 664	2
59	.53 370	.97 303	.56 067	.43 933	.02 697	.46 630	1
60	9.53 405	9.97 299	9.56 107	9.43 893	0.02 701	0.46 595	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

109° (289°) (250°) 70°

20° (200°) (339°) **159°**

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.53 405	9.97 299	9.56 107	0.43 893	0.02 701	0.46 595	**60**
1	.53 440	.97 294	.56 146	.43 854	.02 706	.46 560	59
2	.53 475	.97 289	.56 185	.43 815	.02 711	.46 525	58
3	.53 509	.97 285	.56 224	.43 776	.02 715	.46 491	57
4	.53 544	.97 280	.56 264	.43 736	.02 720	.46 456	56
5	9.53 578	9.97 276	9.56 303	0.43 697	0.02 724	0.46 422	**55**
6	.53 613	.97 271	.56 342	.43 658	.02 729	.46 387	54
7	.53 647	.97 266	.56 381	.43 619	.02 734	.46 353	53
8	.53 682	.97 262	.56 420	.43 580	.02 738	.46 318	52
9	.53 716	.97 257	.56 459	.43 541	.02 743	.46 284	51
10	9.53 751	9.97 252	9.56 498	0.43 502	0.02 748	0.46 249	**50**
11	.53 785	.97 248	.56 537	.43 463	.02 752	.46 215	49
12	.53 819	.97 243	.56 576	.43 424	.02 757	.46 181	48
13	.53 854	.97 238	.56 615	.43 385	.02 762	.46 146	47
14	.53 888	.97 234	.56 654	.43 346	.02 766	.46 112	46
15	9.53 922	9.97 229	9.56 693	0.43 307	0.02 771	0.46 078	**45**
16	.53 957	.97 224	.56 732	.43 268	.02 776	.46 043	44
17	.53 991	.97 220	.56 771	.43 229	.02 780	.46 009	43
18	.54 025	.97 215	.56 810	.43 190	.02 785	.45 975	42
19	.54 059	.97 210	.56 849	.43 151	.02 790	.45 941	41
20	9.54 093	9.97 206	9.56 887	0.43 113	0.02 794	0.45 907	**40**
21	.54 127	.97 201	.56 926	.43 074	.02 799	.45 873	39
22	.54 161	.97 196	.56 965	.43 035	.02 804	.45 839	38
23	.54 195	.97 192	.57 004	.42 996	.02 808	.45 805	37
24	.54 229	.97 187	.57 042	.42 958	.02 813	.45 771	36
25	9.54 263	9.97 182	9.57 081	0.42 919	0.02 818	0.45 737	**35**
26	.54 297	.97 178	.57 120	.42 880	.02 822	.45 703	34
27	.54 331	.97 173	.57 158	.42 842	.02 827	.45 669	33
28	.54 365	.97 168	.57 197	.42 803	.02 832	.45 635	32
29	.54 399	.97 163	.57 235	.42 765	.02 837	.45 601	31
30	9.54 433	9.97 159	9.57 274	0.42 726	0.02 841	0.45 567	**30**
31	.54 466	.97 154	.57 312	.42 688	.02 846	.45 534	29
32	.54 500	.97 149	.57 351	.42 649	.02 851	.45 500	28
33	.54 534	.97 145	.57 389	.42 611	.02 855	.45 466	27
34	.54 567	.97 140	.57 428	.42 572	.02 860	.45 433	26
35	9.54 601	9.97 135	9.57 466	0.42 534	0.02 865	0.45 399	**25**
36	.54 635	.97 130	.57 504	.42 496	.02 870	.45 365	24
37	.54 668	.97 126	.57 543	.42 457	.02 874	.45 332	23
38	.54 702	.97 121	.57 581	.42 419	.02 879	.45 298	22
39	.54 735	.97 116	.57 619	.42 381	.02 884	.45 265	21
40	9.54 769	9.97 111	9.57 658	0.42 342	0.02 889	0.45 231	**20**
41	.54 802	.97 107	.57 696	.42 304	.02 893	.45 198	19
42	.54 836	.97 102	.57 734	.42 266	.02 898	.45 164	18
43	.54 869	.97 097	.57 772	.42 228	.02 903	.45 131	17
44	.54 903	.97 092	.57 810	.42 190	.02 908	.45 097	16
45	9.54 936	9.97 087	9.57 849	0.42 151	0.02 913	0.45 064	**15**
46	.54 969	.97 083	.57 887	.42 113	.02 917	.45 031	14
47	.55 003	.97 078	.57 925	.42 075	.02 922	.44 997	13
48	.55 036	.97 073	.57 963	.42 037	.02 927	.44 964	12
49	.55 069	.97 068	.58 001	.41 999	.02 932	.44 931	11
50	9.55 102	9.97 063	9.58 039	0.41 961	0.02 937	0.44 898	**10**
51	.55 136	.97 059	.58 077	.41 923	.02 941	.44 864	9
52	.55 169	.97 054	.58 115	.41 885	.02 946	.44 831	8
53	.55 202	.97 049	.58 153	.41 847	.02 951	.44 798	7
54	.55 235	.97 044	.58 191	.41 809	.02 956	.44 765	6
55	9.55 268	9.97 039	9.58 229	0.41 771	0.02 961	0.44 732	**5**
56	.55 301	.97 035	.58 267	.41 733	.02 965	.44 699	4
57	.55 334	.97 030	.58 304	.41 696	.02 970	.44 666	3
58	.55 367	.97 025	.58 342	.41 658	.02 975	.44 633	2
59	.55 400	.97 020	.58 380	.41 620	.02 980	.44 600	1
60	9.55 433	9.97 015	9.58 418	0.41 582	0.02 985	0.44 567	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

110° (290°) (249°) **59°**

21° (201°) (338°) **158°**

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.55 433	9.97 015	9.58 418	0.41 582	0.02 985	0.44 567	**60**
1	.55 466	.97 010	.58 455	.41 545	.02 990	.44 534	59
2	.55 499	.97 005	.58 493	.41 507	.02 995	.44 501	58
3	.55 532	.97 001	.58 531	.41 469	.02 999	.44 468	57
4	.55 564	.96 996	.58 569	.41 431	.03 004	.44 436	56
5	9.55 597	9.96 991	9.58 606	0.41 394	0.03 009	0.44 403	**55**
6	.55 630	.96 986	.58 644	.41 356	.03 014	.44 370	54
7	.55 663	.96 981	.58 681	.41 319	.03 019	.44 337	53
8	.55 695	.96 976	.58 719	.41 281	.03 024	.44 305	52
9	.55 728	.96 971	.58 757	.41 243	.03 029	.44 272	51
10	9.55 761	9.96 966	9.58 794	0.41 206	0.03 034	0.44 239	**50**
11	.55 793	.96 962	.58 832	.41 168	.03 038	.44 207	49
12	.55 826	.96 957	.58 869	.41 131	.03 043	.44 174	48
13	.55 858	.96 952	.58 907	.41 093	.03 048	.44 142	47
14	.55 891	.96 947	.58 944	.41 056	.03 053	.44 109	46
15	9.55 923	9.96 942	9.58 981	0.41 019	0.03 058	0.44 077	**45**
16	.55 956	.96 937	.59 019	.40 981	.03 063	.44 044	44
17	.55 988	.96 932	.59 056	.40 944	.03 068	.44 012	43
18	.56 021	.96 927	.59 094	.40 906	.03 073	.43 979	42
19	.56 053	.96 922	.59 131	.40 869	.03 078	.43 947	41
20	9.56 085	9.96 917	9.59 168	0.40 832	0.03 083	0.43 915	**40**
21	.56 118	.96 912	.59 205	.40 795	.03 088	.43 882	39
22	.56 150	.96 907	.59 243	.40 757	.03 093	.43 850	38
23	.56 182	.96 903	.59 280	.40 720	.03 097	.43 818	37
24	.56 215	.96 898	.59 317	.40 683	.03 102	.43 785	36
25	9.56 247	9.96 893	9.59 354	0.40 646	0.03 107	0.43 753	**35**
26	.56 279	.96 888	.59 391	.40 609	.03 112	.43 721	34
27	.56 311	.96 883	.59 429	.40 571	.03 117	.43 689	33
28	.56 343	.96 878	.59 466	.40 534	.03 122	.43 657	32
29	.56 375	.96 873	.59 503	.40 497	.03 127	.43 625	31
30	9.56 408	9.96 868	9.59 540	0.40 460	0.03 132	0.43 592	**30**
31	.56 440	.96 863	.59 577	.40 423	.03 137	.43 560	29
32	.56 472	.96 858	.59 614	.40 386	.03 142	.43 528	28
33	.56 504	.96 853	.59 651	.40 349	.03 147	.43 496	27
34	.56 536	.96 848	.59 688	.40 312	.03 152	.43 464	26
35	9.56 568	9.96 843	9.59 725	0.40 275	0.03 157	0.43 432	**25**
36	.56 599	.96 838	.59 762	.40 238	.03 162	.43 401	24
37	.56 631	.96 833	.59 799	.40 201	.03 167	.43 369	23
38	.56 663	.96 828	.59 835	.40 165	.03 172	.43 337	22
39	.56 695	.96 823	.59 872	.40 128	.03 177	.43 305	21
40	9.56 727	9.96 818	9.59 909	0.40 091	0.03 182	0.43 273	**20**
41	.56 759	.96 813	.59 946	.40 054	.03 187	.43 241	19
42	.56 790	.96 808	.59 983	.40 017	.03 192	.43 210	18
43	.56 822	.96 803	.60 019	.39 981	.03 197	.43 178	17
44	.56 854	.96 798	.60 056	.39 944	.03 202	.43 146	16
45	9.56 886	9.96 793	9.60 093	0.39 907	0.03 207	0.43 114	**15**
46	.56 917	.96 788	.60 130	.39 870	.03 212	.43 083	14
47	.56 949	.96 783	.60 166	.39 834	.03 217	.43 051	13
48	.56 980	.96 778	.60 203	.39 797	.03 222	.43 020	12
49	.57 012	.96 772	.60 240	.39 760	.03 228	.42 988	11
50	9.57 044	9.96 767	9.60 276	0.39 724	0.03 233	0.42 956	**10**
51	.57 075	.96 762	.60 313	.39 687	.03 238	.42 925	9
52	.57 107	.96 757	.60 349	.39 651	.03 243	.42 893	8
53	.57 138	.96 752	.60 386	.39 614	.03 248	.42 862	7
54	.57 169	.96 747	.60 422	.39 578	.03 253	.42 831	6
55	9.57 201	9.96 742	9.60 459	0.39 541	0.03 258	0.42 799	**5**
56	.57 232	.96 737	.60 495	.39 505	.03 263	.42 768	4
57	.57 264	.96 732	.60 532	.39 468	.03 268	.42 736	3
58	.57 295	.96 727	.60 568	.39 432	.03 273	.42 705	2
59	.57 326	.96 722	.60 605	.39 395	.03 278	.42 674	1
60	9.57 358	9.96 717	9.60 641	0.39 359	0.03 283	0.42 642	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

111° (291°) (248°) **68°**

22° (202°) (337°) **157°**

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.57 358	9.96 717	9.60 641	0.39 359	0.03 283	0.42 642	**60**
1	.57 389	.96 711	.60 677	.39 323	.03 289	.42 611	59
2	.57 420	.96 706	.60 714	.39 286	.03 294	.42 580	58
3	.57 451	.96 701	.60 750	.39 250	.03 299	.42 549	57
4	.57 482	.96 696	.60 786	.39 214	.03 304	.42 518	56
5	9.57 514	9.96 691	9.60 823	0.39 177	0.03 309	0.42 486	**55**
6	.57 545	.96 686	.60 859	.39 141	.03 314	.42 455	54
7	.57 576	.96 681	.60 895	.39 105	.03 319	.42 424	53
8	.57 607	.96 676	.60 931	.39 069	.03 324	.42 393	52
9	.57 638	.96 670	.60 967	.39 033	.03 330	.42 362	51
10	9.57 669	9.96 665	9.61 004	9.38 996	0.03 335	0.42 331	**50**
11	.57 700	.96 660	.61 040	.38 960	.03 340	.42 300	49
12	.57 731	.96 655	.61 076	.38 924	.03 345	.42 269	48
13	.57 762	.96 650	.61 112	.38 888	.03 350	.42 238	47
14	.57 793	.96 645	.61 148	.38 852	.03 355	.42 207	46
15	9.57 824	9.96 640	9.61 184	0.38 816	0.03 360	0.42 176	**45**
16	.57 855	.96 634	.61 220	.38 780	.03 366	.42 145	44
17	.57 885	.96 629	.61 256	.38 744	.03 371	.42 115	43
18	.57 916	.96 624	.61 292	.38 708	.03 376	.42 084	42
19	.57 947	.96 619	.61 328	.38 672	.03 381	.42 053	41
20	9.57 978	9.96 614	9.61 364	0.38 636	0.03 386	0.42 022	**40**
21	.58 008	.96 608	.61 400	.38 600	.03 392	.41 992	39
22	.58 039	.96 603	.61 436	.38 564	.03 397	.41 961	38
23	.58 070	.96 598	.61 472	.38 528	.03 402	.41 930	37
24	.58 101	.96 593	.61 508	.38 492	.03 407	.41 899	36
25	9.58 131	9.96 588	9.61 544	0.38 456	0.03 412	0.41 869	**35**
26	.58 162	.96 582	.61 579	.38 421	.03 418	.41 838	34
27	.58 192	.96 577	.61 615	.38 385	.03 423	.41 808	33
28	.58 223	.96 572	.61 651	.38 349	.03 428	.41 777	32
29	.58 253	.96 567	.61 687	.38 313	.03 433	.41 747	31
30	9.58 284	9.96 562	9.61 722	0.38 278	0.03 438	0.41 716	**30**
31	.58 314	.96 556	.61 758	.38 242	.03 444	.41 686	29
32	.58 345	.96 551	.61 794	.38 206	.03 449	.41 655	28
33	.58 375	.96 546	.61 830	.38 170	.03 454	.41 625	27
34	.58 406	.96 541	.61 865	.38 135	.03 459	.41 594	26
35	9.58 436	9.96 535	9.61 901	0.38 099	0.03 465	0.41 564	**25**
36	.58 467	.96 530	.61 936	.38 064	.03 470	.41 533	24
37	.58 497	.96 525	.61 972	.38 028	.03 475	.41 503	23
38	.58 527	.96 520	.62 008	.37 992	.03 480	.41 473	22
39	.58 557	.96 514	.62 043	.37 957	.03 486	.41 443	21
40	9.58 588	9.96 509	9.62 079	0.37 921	0.03 491	0.41 412	**20**
41	.58 618	.96 504	.62 114	.37 886	.03 496	.41 382	19
42	.58 648	.96 498	.62 150	.37 850	.03 502	.41 352	18
43	.58 678	.96 493	.62 185	.37 815	.03 507	.41 322	17
44	.58 709	.96 488	.62 221	.37 779	.03 512	.41 291	16
45	9.58 739	9.96 483	9.62 256	0.37 744	0.03 517	0.41 261	**15**
46	.58 769	.96 477	.62 292	.37 708	.03 523	.41 231	14
47	.58 799	.96 472	.62 327	.37 673	.03 528	.41 201	13
48	.58 829	.96 467	.62 362	.37 638	.03 533	.41 171	12
49	.58 859	.96 461	.62 398	.37 602	.03 539	.41 141	11
50	9.58 889	9.96 456	9.62 433	0.37 567	0.03 544	0.41 111	**10**
51	.58 919	.96 451	.62 468	.37 532	.03 549	.41 081	9
52	.58 949	.96 445	.62 504	.37 496	.03 555	.41 051	8
53	.58 979	.96 440	.62 539	.37 461	.03 560	.41 021	7
54	.59 009	.96 435	.62 574	.37 426	.03 565	.40 991	6
55	9.59 039	9.96 429	9.62 609	0.37 391	0.03 571	0.40 961	**5**
56	.59 069	.96 424	.62 645	.37 355	.03 576	.40 931	4
57	.59 098	.96 419	.62 680	.37 320	.03 581	.40 902	3
58	.59 128	.96 413	.62 715	.37 285	.03 587	.40 872	2
59	.59 158	.96 408	.62 750	.37 250	.03 592	.40 842	1
60	9.59 188	9.96 403	9.62 785	0.37 215	0.03 597	0.40 812	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

112° (292°) (247°) **67°**

23° (203°) (336°) **156°**

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.59 188	9.96 403	9.62 785	0.37 215	0.03 597	0.40 812	**60**
1	.59 218	.96 397	.62 820	.37 180	.03 603	.40 782	59
2	.59 247	.96 392	.62 855	.37 145	.03 608	.40 753	58
3	.59 277	.96 387	.62 890	.37 110	.03 613	.40 723	57
4	.59 307	.96 381	.62 926	.37 074	.03 619	.40 693	56
5	9.59 336	9.96 376	9.62 961	0.37 039	0.03 624	0.40 664	**55**
6	.59 366	.96 370	.62 996	.37 004	.03 630	.40 634	54
7	.59 396	.96 365	.63 031	.36 969	.03 635	.40 604	53
8	.59 425	.96 360	.63 066	.36 934	.03 640	.40 575	52
9	.59 455	.96 354	.63 101	.36 899	.03 646	.40 545	51
10	9.59 484	9.96 349	9.63 135	0.36 865	0.03 651	0.40 516	**50**
11	.59 514	.96 343	.63 170	.36 830	.03 657	.40 486	49
12	.59 543	.96 338	.63 205	.36 795	.03 662	.40 457	48
13	.59 573	.96 333	.63 240	.36 760	.03 667	.40 427	47
14	.59 602	.96 327	.63 275	.36 725	.03 673	.40 398	46
15	9.59 632	9.96 322	9.63 310	0.36 690	0.03 678	0.40 368	**45**
16	.59 661	.96 316	.63 345	.36 655	.03 684	.40 339	44
17	.59 690	.96 311	.63 379	.36 621	.03 689	.40 310	43
18	.59 720	.96 305	.63 414	.36 586	.03 695	.40 280	42
19	.59 749	.96 300	.63 449	.36 551	.03 700	.40 251	41
20	9.59 778	9.96 294	9.63 484	0.36 516	0.03 706	0.40 222	**40**
21	.59 808	.96 289	.63 519	.36 481	.03 711	.40 192	39
22	.59 837	.96 284	.63 553	.36 447	.03 716	.40 163	38
23	.59 866	.96 278	.63 588	.36 412	.03 722	.40 134	37
24	.59 895	.96 273	.63 623	.36 377	.03 727	.40 105	36
25	9.59 924	9.96 267	9.63 657	0.36 343	0.03 733	0.40 076	**35**
26	.59 954	.96 262	.63 692	.36 308	.03 738	.40 046	34
27	.59 983	.96 256	.63 726	.36 274	.03 744	.40 017	33
28	.60 012	.96 251	.63 761	.36 239	.03 749	.39 988	32
29	.60 041	.96 245	.63 796	.36 204	.03 755	.39 959	31
30	9.60 070	9.96 240	9.63 830	0.36 170	0.03 760	.39 930	**30**
31	.60 099	.96 234	.63 865	.36 135	.03 766	.39 901	29
32	.60 128	.96 229	.63 899	.36 101	.03 771	.39 872	28
33	.60 157	.96 223	.63 934	.36 066	.03 777	.39 843	27
34	.60 186	.96 218	.63 968	.36 032	.03 782	.39 814	26
35	9.60 215	9.96 212	9.64 003	0.35 997	0.03 788	0.39 785	**25**
36	.60 244	.96 207	.64 037	.35 963	.03 793	.39 756	24
37	.60 273	.96 201	.64 072	.35 928	.03 799	.39 727	23
38	.60 302	.96 196	.64 106	.35 894	.03 804	.39 698	22
39	.60 331	.96 190	.64 140	.35 860	.03 810	.39 669	21
40	9.60 359	9.96 185	9.64 175	0.35 825	0.03 815	0.39 641	**20**
41	.60 388	.96 179	.64 209	.35 791	.03 821	.39 612	19
42	.60 417	.96 174	.64 243	.35 757	.03 826	.39 583	18
43	.60 446	.96 168	.64 278	.35 722	.03 832	.39 554	17
44	.60 474	.96 162	.64 312	.35 688	.03 838	.39 526	16
45	9.60 503	9.96 157	9.64 346	0.35 654	0.03 843	0.39 497	**15**
46	.60 532	.96 151	.64 381	.35 619	.03 849	.39 468	14
47	.60 561	.96 146	.64 415	.35 585	.03 854	.39 439	13
48	.60 589	.96 140	.64 449	.35 551	.03 860	.39 411	12
49	.60 618	.96 135	.64 483	.35 517	.03 865	.39 382	11
50	9.60 646	9.96 129	9.64 517	0.35 483	0.03 871	0.39 354	**10**
51	.60 675	.96 123	.64 552	.35 448	.03 877	.39 325	9
52	.60 704	.96 118	.64 586	.35 414	.03 882	.39 296	8
53	.60 732	.96 112	.64 620	.35 380	.03 888	.39 268	7
54	.60 761	.96 107	.64 654	.35 346	.03 893	.39 239	6
55	9.60 789	9.96 101	9.64 688	0.35 312	0.03 899	0.39 211	**5**
56	.60 818	.96 095	.64 722	.35 278	.03 905	.39 182	4
57	.60 846	.96 090	.64 756	.35 244	.03 910	.39 154	3
58	.60 875	.96 084	.64 790	.35 210	.03 916	.39 125	2
59	.60 903	.96 079	.64 824	.35 176	.03 921	.39 097	1
60	9.60 931	9.96 073	9.64 858	0.35 142	0.03 927	0.39 069	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

113° (293°) (246°) **66°**

24° (204°) (335°) **155°**

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.60 931	9.96 073	9.64 858	0.35 142	0.03 927	0.39 069	**60**
1	.60 960	.96 067	.64 892	.35 108	.03 933	.39 040	59
2	.60 988	.96 062	.64 926	.35 074	.03 938	.39 012	58
3	.61 016	.96 056	.64 960	.35 040	.03 944	.38 984	57
4	.61 045	.96 050	.64 994	.35 006	.03 950	.38 955	56
5	9.61 073	9.96 045	9.65 028	0.34 972	0.03 955	0.38 927	**55**
6	.61 101	.96 039	.65 062	.34 938	.03 961	.38 899	54
7	.61 129	.96 034	.65 096	.34 904	.03 966	.38 871	53
8	.61 158	.96 028	.65 130	.34 870	.03 972	.38 842	52
9	.61 186	.96 022	.65 164	.34 836	.03 978	.38 814	51
10	9.61 214	9.96 017	9.65 197	0.34 803	0.03 983	0.38 786	**50**
11	.61 242	.96 011	.65 231	.34 769	.03 989	.38 758	49
12	.61 270	.96 005	.65 265	.34 735	.03 995	.38 730	48
13	.61 298	.96 000	.65 299	.34 701	.04 000	.38 702	47
14	.61 326	.95 994	.65 333	.34 667	.04 006	.38 674	46
15	9.61 354	9.95 988	9.65 366	0.34 634	0.04 012	0.38 646	**45**
16	.61 382	.95 982	.65 400	.34 600	.04 018	.38 618	44
17	.61 411	.95 977	.65 434	.34 566	.04 023	.38 589	43
18	.61 438	.95 971	.65 467	.34 533	.04 029	.38 562	42
19	.61 466	.95 965	.65 501	.34 499	.04 035	.38 534	41
20	9.61 494	9.95 960	9.65 535	0.34 465	0.04 040	0.38 506	**40**
21	.61 522	.95 954	.65 568	.34 432	.04 046	.38 478	39
22	.61 550	.95 948	.65 602	.34 398	.04 052	.38 450	38
23	.61 578	.95 942	.65 636	.34 364	.04 058	.38 422	37
24	.61 606	.95 937	.65 669	.34 331	.04 063	.38 394	36
25	9.61 634	9.95 931	9.65 703	0.34 297	0.04 069	0.38 366	**35**
26	.61 662	.95 925	.65 736	.34 264	.04 075	.38 338	34
27	.61 689	.95 920	.65 770	.34 230	.04 080	.38 311	33
28	.61 717	.95 914	.65 803	.34 197	.04 086	.38 283	32
29	.61 745	.95 908	.65 837	.34 163	.04 092	.38 255	31
30	9.61 773	9.95 902	9.65 870	0.34 130	0.04 098	0.38 227	**30**
31	.61 800	.95 897	.65 904	.34 096	.04 103	.38 200	29
32	.61 828	.95 891	.65 937	.34 063	.04 109	.38 172	28
33	.61 856	.95 885	.65 971	.34 029	.04 115	.38 144	27
34	.61 883	.95 879	.66 004	.33 996	.04 121	.38 117	26
35	9.61 911	9.95 873	9.66 038	0.33 962	0.04 127	0.38 089	**25**
36	.61 939	.95 868	.66 071	.33 929	.04 132	.38 061	24
37	.61 966	.95 862	.66 104	.33 896	.04 138	.38 034	23
38	.61 994	.95 856	.66 138	.33 862	.04 144	.38 006	22
39	.62 021	.95 850	.66 171	.33 829	.04 150	.37 979	21
40	9.62 049	9.95 844	9.66 204	0.33 796	0.04 156	0.37 951	**20**
41	.62 076	.95 839	.66 238	.33 762	.04 161	.37 924	19
42	.62 104	.95 833	.66 271	.33 729	.04 167	.37 896	18
43	.62 131	.95 827	.66 304	.33 696	.04 173	.37 869	17
44	.62 159	.95 821	.66 337	.33 663	.04 179	.37 841	16
45	9.62 186	9.95 815	9.66 371	0.33 629	0.04 185	0.37 814	**15**
46	.62 214	.95 810	.66 404	.33 596	.04 190	.37 786	14
47	.62 241	.95 804	.66 437	.33 563	.04 196	.37 759	13
48	.62 268	.95 798	.66 470	.33 530	.04 202	.37 732	12
49	.62 296	.95 792	.66 503	.33 497	.04 208	.37 704	11
50	9.62 323	9.95 786	9.66 537	0.33 463	0.04 214	0.37 677	**10**
51	.62 350	.95 780	.66 570	.33 430	.04 220	.37 650	9
52	.62 377	.95 775	.66 603	.33 397	.04 225	.37 623	8
53	.62 405	.95 769	.66 636	.33 364	.04 231	.37 595	7
54	.62 432	.95 763	.66 669	.33 331	.04 237	.37 568	6
55	9.62 459	9.95 757	9.66 702	0.33 298	0.04 243	0.37 541	**5**
56	.62 486	.95 751	.66 735	.33 265	.04 249	.37 514	4
57	.62 513	.95 745	.66 768	.33 232	.04 255	.37 487	3
58	.62 541	.95 739	.66 801	.33 199	.04 261	.37 459	2
59	.62 568	.95 733	.66 834	.33 166	.04 267	.37 432	1
60	9.62 595	9.95 728	9.66 867	0.33 133	0.04 272	0.37 405	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

114° (294°) (245°) **65°**

25° (205°) (334°) **154°**

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.62 595	9.95 728	9.66 867	0.33 133	0.04 272	0.37 405	**60**
1	.62 622	.95 722	.66 900	.33 100	.04 278	.37 378	59
2	.62 649	.95 716	.66 933	.33 067	.04 284	.37 351	58
3	.62 676	.95 710	.66 966	.33 034	.04 290	.37 324	57
4	.62 703	.95 704	.66 999	.33 001	.04 296	.37 297	56
5	9.62 730	9.95 698	9.67 032	0.32 968	0.04 302	0.37 270	**55**
6	.62 757	.95 692	.67 065	.32 935	.04 308	.37 243	54
7	.62 784	.95 686	.67 098	.32 902	.04 314	.37 216	53
8	.62 811	.95 680	.67 131	.32 869	.04 320	.37 189	52
9	.62 838	.95 674	.67 163	.32 837	.04 326	.37 162	51
10	9.62 865	9.95 668	9.67 196	0.32 804	0.04 332	0.37 135	**50**
11	.62 892	.95 663	.67 229	.32 771	.04 337	.37 108	49
12	.62 918	.95 657	.67 262	.32 738	.04 343	.37 082	48
13	.62 945	.95 651	.67 295	.32 705	.04 349	.37 055	47
14	.62 972	.95 645	.67 327	.32 673	.04 355	.37 028	46
15	9.62 999	9.95 639	9.67 360	0.32 640	0.04 361	0.37 001	**45**
16	.63 026	.95 633	.67 393	.32 607	.04 367	.36 974	44
17	.63 052	.95 627	.67 426	.32 574	.04 373	.36 948	43
18	.63 079	.95 621	.67 458	.32 542	.04 379	.36 921	42
19	.63 106	.95 615	.67 491	.32 509	.04 385	.36 894	41
20	9.63 133	9.95 609	9.67 524	0.32 476	0.04 391	0.36 867	**40**
21	.63 159	.95 603	.67 556	.32 444	.04 397	.36 841	39
22	.63 186	.95 597	.67 589	.32 411	.04 403	.36 814	38
23	.63 213	.95 591	.67 622	.32 378	.04 409	.36 787	37
24	.63 239	.95 585	.67 654	.32 346	.04 415	.36 761	36
25	9.63 266	9.95 579	9.67 687	0.32 313	0.04 421	0.36 734	**35**
26	.63 292	.95 573	.67 719	.32 281	.04 427	.36 708	34
27	.63 319	.95 567	.67 752	.32 248	.04 433	.36 681	33
28	.63 345	.95 561	.67 785	.32 215	.04 439	.36 655	32
29	.63 372	.95 555	.67 817	.32 183	.04 445	.36 628	31
30	9.63 398	9.95 549	9.67 850	0.32 150	0.04 451	0.36 602	**30**
31	.63 425	.95 543	.67 882	.32 118	.04 457	.36 575	29
32	.63 451	.95 537	.67 915	.32 085	.04 463	.36 549	28
33	.63 478	.95 531	.67 947	.32 053	.04 469	.36 522	27
34	.63 504	.95 525	.67 980	.32 020	.04 475	.36 496	26
35	9.63 531	9.95 519	9.68 012	0.31 988	0.04 481	0.36 469	**25**
36	.63 557	.95 513	.68 044	.31 956	.04 487	.36 443	24
37	.63 583	.95 507	.68 077	.31 923	.04 493	.36 417	23
38	.63 610	.95 500	.68 109	.31 891	.04 500	.36 390	22
39	.63 636	.95 494	.68 142	.31 858	.04 506	.36 364	21
40	9.63 662	9.95 488	9.68 174	0.31 826	0.04 512	0.36 338	**20**
41	.63 689	.95 482	.68 206	.31 794	.04 518	36 311	19
42	.63 715	.95 476	.68 239	.31 761	.04 524	.36 285	18
43	.63 741	.95 470	.68 271	.31 729	.04 530	.36 259	17
44	.63 767	.95 464	.68 303	.31 697	.04 536	.36 233	16
45	9.63 794	9.95 458	9.68 336	0.31 664	0.04 542	0.36 206	**15**
46	.63 820	.95 452	.68 368	.31 632	.04 548	.36 180	14
47	.63 846	.95 446	.68 400	.31 600	.04 554	.36 154	13
48	.63 872	.95 440	.68 432	.31 568	.04 560	.36 128	12
49	.63 898	.95 434	.68 465	.31 535	.04 566	.36 102	11
50	9.63 924	9.95 427	9.68 497	0.31 503	0.04 573	0.36 076	**10**
51	.63 950	.95 421	.68 529	.31 471	.04 579	.36 050	9
52	.63 976	.95 415	.68 561	.31 439	.04 585	.36 024	8
53	.64 002	.95 409	.68 593	.31 407	.04 591	.35 998	7
54	.64 028	.95 403	.68 626	.31 374	.04 597	.35 972	6
55	9.64 054	9.95 397	9.68 658	0.31 342	0.04 603	0.35 946	**5**
56	.64 080	.95 391	.68 690	.31 310	.04 609	.35 920	4
57	.64 106	.95 384	.68 722	.31 278	.04 616	.35 894	3
58	.64 132	.95 378	.68 754	.31 246	.04 622	.35 868	2
59	.64 158	.95 372	.68 786	.31 214	.04 628	.35 842	1
60	9.64 184	9.95 366	9.68 818	0.31 182	0.04 634	0.35 816	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

115° (295°) (244°) **64°**

26° (206°) (333°) **153°**

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.64 184	9.95 366	9.68 818	0.31 182	0.04 634	0.35 816	**60**
1	.64 210	.95 360	.68 850	.31 150	.04 640	.35 790	59
2	.64 236	.95 354	.68 882	.31 118	.04 646	.35 764	58
3	.64 262	.95 348	.68 914	.31 086	.04 652	.35 738	57
4	.64 288	.95 341	.68 946	.31 054	.04 659	.35 712	56
5	9.64 313	9.95 335	9.68 978	0.31 022	0.04 665	0.35 687	**55**
6	.64 339	.95 329	.69 010	.30 990	.04 671	.35 661	54
7	.64 365	.95 323	.69 042	.30 958	.04 677	.35 635	53
8	.64 391	.95 317	.69 074	.30 926	.04 683	.35 609	52
9	.64 417	.95 310	.69 106	.30 894	.04 690	.35 583	51
10	9.64 442	9.95 304	9.69 138	0.30 862	0.04 696	0.35 558	**50**
11	.64 468	.95 298	.69 170	.30 830	.04 702	.35 532	49
12	.64 494	.95 292	.69 202	.30 798	.04 708	.35 506	48
13	.64 519	.95 286	.69 234	.30 766	.04 714	.35 481	47
14	.64 545	.95 279	.69 266	.30 734	.04 721	.35 455	46
15	9.64 571	9.95 273	9.69 298	0.30 702	0.04 727	0.35 429	**45**
16	.64 596	.95 267	.69 329	.30 671	.04 733	.35 404	44
17	.64 622	.95 261	.69 361	.30 639	.04 739	.35 378	43
18	.64 647	.95 254	.69 393	.30 607	.04 746	.35 353	42
19	.64 673	.95 248	.69 425	.30 575	.04 752	.35 327	41
20	9.64 698	9.95 242	9.69 457	0.30 543	0.04 758	0.35 302	**40**
21	.64 724	.95 236	.69 488	.30 512	.04 764	.35 276	39
22	.64 749	.95 229	.69 520	.30 480	.04 771	.35 251	38
23	.64 775	.95 223	.69 552	.30 448	.04 777	.35 225	37
24	.64 800	.95 217	.69 584	.30 416	.04 783	.35 200	36
25	9.64 826	9.95 211	9.69 615	0.30 385	0.04 789	0.35 174	**35**
26	.64 851	.95 204	.69 647	.30 353	.04 796	.35 149	34
27	.64 877	.95 198	.69 679	.30 321	.04 802	.35 123	33
28	.64 902	.95 192	.69 710	.30 290	.04 808	.35 098	32
29	.64 927	.95 185	.69 742	.30 258	.04 815	.35 073	31
30	9.64 953	9.95 179	9.69 774	0.30 226	0.04 821	0.35 047	**30**
31	.64 978	.95 173	.69 805	.30 195	.04 827	.35 022	29
32	.65 003	.95 167	.69 837	.30 163	.04 833	.34 997	28
33	.65 029	.95 160	.69 868	.30 132	.04 840	.34 971	27
34	.65 054	.95 154	.69 900	.30 100	.04 846	.34 946	26
35	9.65 079	9.95 148	9.69 932	0.30 068	0.04 852	0.34 921	**25**
36	.65 104	.95 141	.69 963	.30 037	.04 859	.34 896	24
37	.65 130	.95 135	.69 995	.30 005	.04 865	.34 870	23
38	.65 155	.95 129	.70 026	.29 974	.04 871	.34 845	22
39	.65 180	.95 122	.70 058	.29 942	.04 878	.34 820	21
40	9.65 205	9.95 116	9.70 089	0.29 911	0.04 884	0.34 795	**20**
41	.65 230	.95 110	.70 121	.29 879	.04 890	.34 770	19
42	.65 255	.95 103	.70 152	.29 848	.04 897	.34 745	18
43	.65 281	.95 097	.70 184	.29 816	.04 903	.34 719	17
44	.65 306	.95 090	.70 215	.29 785	.04 910	.34 694	16
45	9.65 331	9.95 084	9.70 247	0.29 753	0.04 916	0.34 669	**15**
46	.65 356	.95 078	.70 278	.29 722	.04 922	.34 644	14
47	.65 381	.95 071	.70 309	.29 691	.04 929	.34 619	13
48	.65 406	.95 065	.70 341	.29 659	.04 935	.34 594	12
49	.65 431	.95 059	.70 372	.29 628	.04 941	.34 569	11
50	9.65 456	9.95 052	9.70 404	0.29 596	0.04 948	0.34 544	**10**
51	.65 481	.95 046	.70 435	.29 565	.04 954	.34 519	9
52	.65 506	.95 039	.70 466	.29 534	.04 961	.34 494	8
53	.65 531	.95 033	.70 498	.29 502	.04 967	.34 469	7
54	.65 556	.95 027	.70 529	.29 471	.04 973	.34 444	6
55	9.65 580	9.95 020	9.70 560	0.29 440	0.04 980	0.34 420	**5**
56	.65 605	.95 014	.70 592	.29 408	.04 986	.34 395	4
57	.65 630	.95 007	.70 623	.29 377	.04 993	.34 370	3
58	.65 655	.95 001	.70 654	.29 346	.04 999	.34 345	2
59	.65 680	.94 995	.70 685	.29 315	.05 005	.34 320	1
60	9.65 705	9.94 988	9.70 717	0.29 283	0.05 012	0.34 295	**0**
	Cos	**Sin**	**Cot**	**Tan**	**Csc**	**Sec**	′

116° (296°) (243°) **63°**

27° (207°) (332°) **152°**

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.65 705	9.94 988	9.70 717	0.29 283	0.05 012	0.34 295	**60**
1	.65 729	.94 982	.70 748	.29 252	.05 018	.34 271	59
2	.65 754	.94 975	.70 779	.29 221	.05 025	.34 246	58
3	.65 779	.94 969	.70 810	.29 190	.05 031	.34 221	57
4	.65 804	.94 962	.70 841	.29 159	.05 038	.34 196	56
5	9.65 828	9.94 956	9.70 873	0.29 127	0.05 044	0.34 172	**55**
6	.65 853	.94 949	.70 904	.29 096	.05 051	.34 147	54
7	.65 878	.94 943	.70 935	.29 065	.05 057	.34 122	53
8	.65 902	.94 936	.70 966	.29 034	.05 064	.34 098	52
9	.65 927	.94 930	.70 997	.29 003	.05 070	.34 073	51
10	9.65 952	9.94 923	9.71 028	0.28 972	0.05 077	0.34 048	**50**
11	.65 976	.94 917	.71 059	.28 941	.05 083	.34 024	49
12	.66 001	.94 911	.71 090	.28 910	.05 089	.33 999	48
13	.66 025	.94 904	.71 121	.28 879	.05 096	.33 975	47
14	.66 050	.94 898	.71 153	.28 847	.05 102	.33 950	46
15	9.66 075	9.94 891	9.71 184	0.28 816	0.05 109	0.33 925	**45**
16	.66 099	.94 885	.71 215	.28 785	.05 115	.33 901	44
17	.66 124	.94 878	.71 246	.28 754	.05 122	.33 876	43
18	.66 148	.94 871	.71 277	.28 723	.05 129	.33 852	42
19	.66 173	.94 865	.71 308	.28 692	.05 135	.33 827	41
20	9.66 197	9.94 858	9.71 339	0.28 661	0.05 142	0.33 803	**40**
21	.66 221	.94 852	.71 370	.28 630	.05 148	.33 779	39
22	.66 246	.94 845	.71 401	.28 599	.05 155	.33 754	38
23	.66 270	.94 839	.71 431	.28 569	.05 161	.33 730	37
24	.66 295	.94 832	.71 462	.28 538	.05 168	.33 705	36
25	9.66 319	9.94 826	9.71 493	0.28 507	0.05 174	0.33 681	**35**
26	.66 343	.94 819	.71 524	.28 476	.05 181	.33 657	34
27	.66 368	.94 813	.71 555	.28 445	.05 187	.33 632	33
28	.66 392	.94 806	.71 586	.28 414	.05 194	.33 608	32
29	.66 416	.94 799	.71 617	.28 383	.05 201	.33 584	31
30	9.66 441	9.94 793	9.71 648	0.28 352	0.05 207	0.33 559	**30**
31	.66 465	.94 786	.71 679	.28 321	.05 214	.33 535	29
32	.66 489	.94 780	.71 709	.28 291	.05 220	.33 511	28
33	.66 513	.94 773	.71 740	.28 260	.05 227	.33 487	27
34	.66 537	.94 767	.71 771	.28 229	.05 233	.33 463	26
35	9.66 562	9.94 760	9.71 802	0.28 198	0.05 240	0.33 438	**25**
36	.66 586	.94 753	.71 833	.28 167	.05 247	.33 414	24
37	.66 610	.94 747	.71 863	.28 137	.05 253	.33 390	23
38	.66 634	.94 740	.71 894	.28 106	.05 260	.33 366	22
39	.66 658	.94 734	.71 925	.28 075	.05 266	.33 342	21
40	9.66 682	9.94 727	9.71 955	0.28 045	0.05 273	0.33 318	**20**
41	.66 706	.94 720	.71 986	.28 014	.05 280	.33 294	19
42	.66 731	.94 714	.72 017	.27 983	.05 286	.33 269	18
43	.66 755	.94 707	.72 048	.27 952	.05 293	.33 245	17
44	.66 779	.94 700	.72 078	.27 922	.05 300	.33 221	16
45	9.66 803	9.94 694	9.72 109	0.27 891	0.05 306	0.33 197	**15**
46	.66 827	.94 687	.72 140	.27 860	.05 313	.33 173	14
47	.66 851	.94 680	.72 170	.27 830	.05 320	.33 149	13
48	.66 875	.94 674	.72 201	.27 799	.05 326	.33 125	12
49	.66 899	.94 667	.72 231	.27 769	.05 333	.33 101	11
50	9.66 922	9.94 660	9.72 262	0.27 738	0.05 340	0.33 078	**10**
51	.66 946	.94 654	.72 293	.27 707	.05 346	.33 054	9
52	.66 970	.94 647	.72 323	.27 677	.05 353	.33 030	8
53	.66 994	.94 640	.72 354	.27 646	.05 360	.33 006	7
54	.67 018	.94 634	.72 384	.27 616	.05 366	.32 982	6
55	9.67 042	9.94 627	9.72 415	0.27 585	0.05 373	0.32 958	**5**
56	.67 066	.94 620	.72 445	.27 555	.05 380	.32 934	4
57	.67 090	.94 614	.72 476	.27 524	.05 386	.32 910	3
58	.67 113	.94 607	.72 506	.27 494	.05 393	.32 887	2
59	.67 137	.94 600	.72 537	.27 463	.05 400	.32 863	1
60	9.67 161	9.94 593	9.72 567	0.27 433	0.05 407	0.32 839	**0**
	Cos	**Sin**	**Cot**	**Tan**	**Csc**	**Sec**	′

117° (297°) (242°) **62°**

28° (208°) (331°) 151°

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.67 161	9.94 593	9.72 567	0.27 433	0.05 407	0.32 839	**60**
1	.67 185	.94 587	.72 598	.27 402	.05 413	.32 815	59
2	.67 208	.94 580	.72 628	.27 372	.05 420	.32 792	58
3	.67 232	.94 573	.72 659	.27 341	.05 427	.32 768	57
4	.67 256	.94 567	.72 689	.27 311	.05 433	.32 744	56
5	9.67 280	9.94 560	9.72 720	0.27 280	0.05 440	0.32 720	**55**
6	.67 303	.94 553	.72 750	.27 250	.05 447	.32 697	54
7	.67 327	.94 546	.72 780	.27 220	.05 454	.32 673	53
8	.67 350	.94 540	.72 811	.27 189	.05 460	.32 650	52
9	.67 374	.94 533	.72 841	.27 159	.05 467	.32 626	51
10	9.67 398	9.94 526	9.72 872	0.27 128	0.05 474	0.32 602	**50**
11	.67 421	.94 519	.72 902	.27 098	.05 481	.32 579	49
12	.67 445	.94 513	.72 932	.27 068	.05 487	.32 555	48
13	.67 468	.94 506	.72 963	.27 037	.05 494	.32 532	47
14	.67 492	.94 499	.72 993	.27 007	.05 501	.32 508	46
15	9.67 515	9.94 492	9.73 023	0.26 977	0.05 508	0.32 485	**45**
16	.67 539	.94 485	.73 054	.26 946	.05 515	.32 461	44
17	.67 562	.94 479	.73 084	.26 916	.05 521	.32 438	43
18	.67 586	.94 472	.73 114	.26 886	.05 528	.32 414	42
19	.67 609	.94 465	.73 144	.26 856	.05 535	.32 391	41
20	9.67 633	9.94 458	9.73 175	0.26 825	0.05 542	0.32 367	**40**
21	.67 656	.94 451	.73 205	.26 795	.05 549	.32 344	39
22	.67 680	.94 445	.73 235	.26 765	.05 555	.32 320	38
23	.67 703	.94 438	.73 265	.26 735	.05 562	.32 297	37
24	.67 726	.94 431	.73 295	.26 705	.05 569	.32 274	36
25	9.67 750	9.94 424	9.73 326	0.26 674	0.05 576	0.32 250	**35**
26	.67 773	.94 417	.73 356	.26 644	.05 583	.32 227	34
27	.67 796	.94 410	.73 386	.26 614	.05 590	.32 204	33
28	.67 820	.94 404	.73 416	.26 584	.05 596	.32 180	32
29	.67 843	.94 397	.73 446	.26 554	.05 603	.32 157	31
30	9.67 866	9.94 390	9.73 476	0.26 524	0.05 610	0.32 134	**30**
31	.67 890	.94 383	.73 507	.26 493	.05 617	.32 110	29
32	.67 913	.94 376	.73 537	.26 463	.05 624	.32 087	28
33	.67 936	.94 369	.73 567	.26 433	.05 631	.32 064	27
34	.67 959	.94 362	.73 597	.26 403	.05 638	.32 041	26
35	9.67 982	9.94 355	9.73 627	0.26 373	0.05 645	0.32 018	**25**
36	.68 006	.94 349	.73 657	.26 343	.05 651	.31 994	24
37	.68 029	.94 342	.73 687	.26 313	.05 658	.31 971	23
38	.68 052	.94 335	.73 717	.26 283	.05 665	.31 948	22
39	.68 075	.94 328	.73 747	.26 253	.05 672	.31 925	21
40	9.68 098	9.94 321	9.73 777	0.26 223	0.05 679	0.31 902	**20**
41	.68 121	.94 314	.73 807	.26 193	.05 686	.31 879	19
42	.68 144	.94 307	.73 837	.26 163	.05 693	.31 856	18
43	.68 167	.94 300	.73 867	.26 133	.05 700	.31 833	17
44	.68 190	.94 293	.73 897	.26 103	.05 707	.31 810	16
45	9.68 213	9.94 286	9.73 927	0.26 073	0.05 714	0.31 787	**15**
46	.68 237	.94 279	.73 957	.26 043	.05 721	.31 763	14
47	.68 260	.94 273	.73 987	.26 013	.05 727	.31 740	13
48	.68 283	.94 266	.74 017	.25 983	.05 734	.31 717	12
49	.68 305	.94 259	.74 047	.25 953	.05 741	.31 695	11
50	9.68 328	9.94 252	9.74 077	0.25 923	0.05 748	0.31 672	**10**
51	.68 351	.94 245	.74 107	.25 893	.05 755	.31 649	9
52	.68 374	.94 238	.74 137	.25 863	.05 762	.31 626	8
53	.68 397	.94 231	.74 166	.25 834	.05 769	.31 603	7
54	.68 420	.94 224	.74 196	.25 804	.05 776	.31 580	6
55	9.68 443	9.94 217	9.74 226	0.25 774	0.05 783	0.31 557	**5**
56	.68 466	.94 210	.74 256	.25 744	.05 790	.31 534	4
57	.68 489	.94 203	.74 286	.25 714	.05 797	.31 511	3
58	.68 512	.94 196	.74 316	.25 684	.05 804	.31 488	2
59	.68 534	.94 189	.74 345	.25 655	.05 811	.31 466	1
60	9.68 557	9.94 182	9.74 375	0.25 625	0.05 818	0.31 443	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

118° (298°) (241°) 61°

29° (209°) (330°) **150°**

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.68 557	9.94 182	9.74 375	0.25 625	0.05 818	0.31 443	**60**
1	.68 580	.94 175	.74 405	.25 595	.05 825	.31 420	59
2	.68 603	.94 168	.74 435	.25 565	.05 832	.31 397	58
3	.68 625	.94 161	.74 465	.25 535	.05 839	.31 375	57
4	.68 648	.94 154	.74 494	.25 506	.05 846	.31 352	56
5	9.68 671	9.94 147	9.74 524	0.25 476	0.05 853	0.31 329	**55**
6	.68 694	.94 140	.74 554	.25 446	.05 860	.31 306	54
7	.68 716	.94 133	.74 583	.25 417	.05 867	.31 284	53
8	.68 739	.94 126	.74 613	.25 387	.05 874	.31 261	52
9	.68 762	.94 119	.74 643	.25 357	.05 881	.31 238	51
10	9.68 784	9.94 112	9.74 673	0.25 327	0.05 888	0.31 216	**50**
11	.68 807	.94 105	.74 702	.25 298	.05 895	.31 193	49
12	.68 829	.94 098	.74 732	.25 268	.05 902	.31 171	48
13	.68 852	.94 090	.74 762	.25 238	.05 910	.31 148	47
14	.68 875	.94 083	.74 791	.25 209	.05 917	.31 125	46
15	9.68 897	9.94 076	9.74 821	0.25 179	0.05 924	0.31 103	**45**
16	.68 920	.94 069	.74 851	.25 149	.05 931	.31 080	44
17	.68 942	.94 062	.74 880	.25 120	.05 938	.31 058	43
18	.68 965	.94 055	.74 910	.25 090	.05 945	.31 035	42
19	.68 987	.94 048	.74 939	.25 061	.05 952	.31 013	41
20	9.69 010	9.94 041	9.74 969	0.25 031	0.05 959	0.30 990	**40**
21	.69 032	.94 034	.74 998	.25 002	.05 966	.30 968	39
22	.69 055	.94 027	.75 028	.24 972	.05 973	.30 945	38
23	.69 077	.94 020	.75 058	.24 942	.05 980	.30 923	37
24	.69 100	.94 012	.75 087	.24 913	.05 988	.30 900	36
25	9.69 122	9.94 005	9.75 117	0.24 883	0.05 995	0.30 878	**35**
26	.69 144	.93 998	.75 146	.24 854	.06 002	.30 856	34
27	.69 167	.93 991	.75 176	.24 824	.06 009	.30 833	33
28	.69 189	.93 984	.75 205	.24 795	.06 016	.30 811	32
29	.69 212	.93 977	.75 235	.24 765	.06 023	.30 788	31
30	9.69 234	9.93 970	9.75 264	0.24 736	0.06 030	0.30 766	**30**
31	.69 256	.93 963	.75 294	.24 706	.06 037	.30 744	29
32	.69 279	.93 955	.75 323	.24 677	.06 045	.30 721	28
33	.69 301	.93 948	.75 353	.24 647	.06 052	.30 699	27
34	.69 323	.93 941	.75 382	.24 618	.06 059	.30 677	26
35	9.69 345	9.93 934	9.75 411	0.24 589	0.06 066	0.30 655	**25**
36	.69 368	.93 927	.75 441	.24 559	.06 073	.30 632	24
37	.69 390	.93 920	.75 470	.24 530	.06 080	.30 610	23
38	.69 412	.93 912	.75 500	.24 500	.06 088	.30 588	22
39	.69 434	.93 905	.75 529	.24 471	.06 095	.30 566	21
40	9.69 456	9.93 898	9.75 558	0.24 442	0.06 102	0.30 544	**20**
41	.69 479	.93 891	.75 588	.24 412	.06 109	.30 521	19
42	.69 501	.93 884	.75 617	.24 383	.06 116	.30 499	18
43	.69 523	.93 876	.75 647	.24 353	.06 124	.30 477	17
44	.69 545	.93 869	.75 676	.24 324	.06 131	.30 455	16
45	9.69 567	9.93 862	9.75 705	0.24 295	0.06 138	0.30 433	**15**
46	.69 589	.93 855	.75 735	.24 265	.06 145	.30 411	14
47	.69 611	.93 847	.75 764	.24 236	.06 153	.30 389	13
48	.69 633	.93 840	.75 793	.24 207	.06 160	.30 367	12
49	.69 655	.93 833	.75 822	.24 178	.06 167	.30 345	11
50	9.69 677	9.93 826	9.75 852	0.24 148	0.06 174	0.30 323	**10**
51	.69 699	.93 819	.75 881	.24 119	.06 181	.30 301	9
52	.69 721	.93 811	.75 910	.24 090	.06 189	.30 279	8
53	.69 743	.93 804	.75 939	.24 061	.06 196	.30 257	7
54	.69 765	.93 797	.75 969	.24 031	.06 203	.30 235	6
55	9.69 787	9.93 789	9.75 998	0.24 002	0.06 211	0.30 213	**5**
56	.69 809	.93 782	.76 027	.23 973	.06 218	.30 191	4
57	.69 831	.93 775	.76 056	.23 944	.06 225	.30 169	3
58	.69 853	.93 768	.76 086	.23 914	.06 232	.30 147	2
59	.69 875	.93 760	.76 115	.23 885	.06 240	.30 125	1
60	9.69 897	9.93 753	9.76 144	0.23 856	0.06 247	0.30 103	**0**
	Cos	**Sin**	**Cot**	**Tan**	**Csc**	**Sec**	′

119° (299°) (240°) **60°**

30° (210°) (329°) **149°**

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.69 897	9.93 753	9.76 144	0.23 856	0.06 247	0.30 103	**60**
1	.69 919	.93 746	.76 173	.23 827	.06 254	.30 081	59
2	.69 941	.93 738	.76 202	.23 798	.06 262	.30 059	58
3	.69 963	.93 731	.76 231	.23 769	.06 269	.30 037	57
4	.69 984	.93 724	.76 261	.23 739	.06 276	.30 016	56
5	9.70 006	9.93 717	9.76 290	0.23 710	0.06 283	0.29 994	**55**
6	.70 028	.93 709	.76 319	.23 681	.06 291	.29 972	54
7	.70 050	.93 702	.76 348	.23 652	.06 298	.29 950	53
8	.70 072	.93 695	.76 377	.23 623	.06 305	.29 928	52
9	.70 093	.93 687	.76 406	.23 594	.06 313	.29 907	51
10	9.70 115	9.93 680	9.76 435	0.23 565	0.06 320	0.29 885	**50**
11	.70 137	.93 673	.76 464	.23 536	.06 327	.29 863	49
12	.70 159	.93 665	.76 493	.23 507	.06 335	.29 841	48
13	.70 180	.93 658	.76 522	.23 478	.06 342	.29 820	45
14	.70 202	.93 650	.76 551	.23 449	.06 350	.29 798	46
15	9.70 224	9.93 643	9.76 580	0.23 420	0.06 357	0.29 776	**45**
16	.70 245	.93 636	.76 609	.23 391	.06 364	.29 755	44
17	.70 267	.93 628	.76 639	.23 361	.06 372	.29 733	43
18	.70 288	.93 621	.76 668	.23 332	.06 379	.29 712	42
19	.70 310	.93 614	.76 697	.23 303	.06 386	.29 690	41
20	9.70 332	9.93 606	9.76 725	0.23 275	0.06 394	0.29 668	**40**
21	.70 353	.93 599	.76 754	.23 246	.06 401	.29 647	39
22	.70 375	.93 591	.76 783	.23 217	.06 409	.29 625	38
23	.70 396	.93 584	.76 812	.23 188	.06 416	.29 604	37
24	.70 418	.93 577	.76 841	.23 159	.06 423	.29 582	36
25	9.70 439	9.93 569	9.76 870	0.23 130	0.06 431	0.29 561	**35**
26	.70 461	.93 562	.76 899	.23 101	.06 438	.29 539	34
27	.70 482	.93 554	.76 928	.23 072	.06 446	.29 518	33
28	.70 504	.93 547	.76 957	.23 043	.06 453	.29 496	32
29	.70 525	.93 539	.76 986	.23 014	.06 461	.29 475	31
30	9.70 547	9.93 532	9.77 015	0.22 985	0.06 468	0.29 453	**30**
31	.70 568	.93 525	.77 044	.22 956	.06 475	.29 432	29
32	.70 590	.93 517	.77 073	.22 927	.06 483	.29 410	28
33	.70 611	.93 510	.77 101	.22 899	.06 490	.29 389	27
34	.70 633	.93 502	.77 130	.22 870	.06 498	.29 367	26
35	9.70 654	9.93 495	9.77 159	0.22 841	0.06 505	0.29 346	**25**
36	.70 675	.93 487	.77 188	.22 812	.06 513	.29 325	24
37	.70 697	.93 480	.77 217	.22 783	.06 520	.29 303	23
38	.70 718	.93 472	.77 246	.22 754	.06 528	.29 282	22
39	.70 739	.93 465	.77 274	.22 726	.06 535	.29 261	21
40	9.70 761	9.93 457	9.77 303	0.22 697	0.06 543	0.29 239	**20**
41	.70 782	.93 450	.77 332	.22 668	.06 550	.29 218	19
42	.70 803	.93 442	.77 361	.22 639	.06 558	.29 197	18
43	.70 824	.93 435	.77 390	.22 610	.06 565	.29 176	17
44	.70 846	.93 427	.77 418	.22 582	.06 573	.29 154	16
45	9.70 867	9.93 420	9.77 447	0.22 553	0.06 580	0.29 133	**15**
46	.70 888	.93 412	.77 476	.22 524	.06 588	.29 112	14
47	.70 909	.93 405	.77 505	.22 495	.06 595	.29 091	13
48	.70 931	.93 397	.77 533	.22 467	.06 603	.29 069	12
49	.70 952	.93 390	.77 562	.22 438	.06 610	.29 048	11
50	9.70 973	9.93 382	9.77 591	0.22 409	0.06 618	0.29 027	**10**
51	.70 994	.93 375	.77 619	.22 381	.06 625	.29 006	9
52	.71 015	.93 367	.77 648	.22 352	.06 633	.28 985	8
53	.71 036	.93 360	.77 677	.22 323	.06 640	.28 964	7
54	.71 058	.93 352	.77 706	.22 294	.06 648	.28 942	6
55	9.71 079	9.93 344	9.77 734	0.22 266	0.06 656	0.28 921	**5**
56	.71 100	.93 337	.77 763	.22 237	.06 663	.28 900	4
57	.71 121	.93 329	.77 791	.22 209	.06 671	.28 879	3
58	.71 142	.93 322	.77 820	.22 180	.06 678	.28 858	2
59	.71 163	.93 314	.77 849	.22 151	.06 686	.28 837	1
60	9.71 184	9.93 307	9.77 877	0.22 123	0.06 693	0.28 816	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

120° (300°) (239°) **59°**

31° (211°) (328°) 148°

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.71 184	9.93 307	9.77 877	0.22 123	0.06 693	0.28 816	**60**
1	.71 205	.93 299	.77 906	.22 094	.06 701	.28 795	59
2	.71 226	.93 291	.77 935	.22 065	.06 709	.28 774	58
3	.71 247	.93 284	.77 963	.22 037	.06 716	.28 753	57
4	.71 268	.93 276	.77 992	.22 008	.06 724	.28 732	56
5	9.71 289	9.93 269	9.78 020	0.21 980	0.06 731	0.28 711	**55**
6	.71 310	.93 261	.78 049	.21 951	.06 739	.28 690	54
7	.71 331	.93 253	.78 077	.21 923	.06 747	.28 669	53
8	.71 352	.93 246	.78 106	.21 894	.06 754	.28 648	52
9	.71 373	.93 238	.78 135	.21 865	.06 762	.28 627	51
10	9.71 393	9.93 230	9.78 163	0.21 837	0.06 770	0.28 607	**50**
11	.71 414	.93 223	.78 192	.21 808	.06 777	.28 586	49
12	.71 435	.93 215	.78 220	.21 780	.06 785	.28 565	48
13	.71 456	.93 207	.78 249	.21 751	.06 793	.28 544	47
14	.71 477	.93 200	.78 277	.21 723	.06 800	.28 523	46
15	9.71 498	9.93 192	9.78 306	0.21 694	0.06 808	0.28 502	**45**
16	.71 519	.93 184	.78 334	.21 666	.06 816	.28 481	44
17	.71 539	.93 177	.78 363	.21 637	.06 823	.28 461	43
18	.71 560	.93 169	.78 391	.21 609	.06 831	.28 440	42
19	.71 581	.93 161	.78 419	.21 581	.06 839	.28 419	41
20	9.71 602	9.93 154	.78 448	0.21 552	0.06 846	0.28 398	**40**
21	.71 622	.93 146	.78 476	.21 524	.06 854	.28 378	39
22	.71 643	.93 138	.78 505	.21 495	.06 862	.28 357	38
23	.71 664	.93 131	.78 533	.21 467	.06 869	.28 336	37
24	.71 685	.93 123	.78 562	.21 438	.06 877	.28 315	36
25	9.71 705	9.93 115	9.78 590	0.21 410	0.06 885	0.28 295	**35**
26	.71 726	.93 108	.78 618	.21 382	.06 892	.28 274	34
27	.71 747	.93 100	.78 647	.21 353	.06 900	.28 253	33
28	.71 767	.93 092	.78 675	.21 325	.06 908	.28 233	32
29	.71 788	.93 084	.78 704	.21 296	.06 916	.28 212	31
30	9.71 809	9.93 077	9.78 732	0.21 268	0.06 923	0.28 191	**30**
31	.71 829	.93 069	.78 760	.21 240	.06 931	.28 171	29
32	.71 850	.93 061	.78 789	.21 211	.06 939	.28 150	28
33	.71 870	.93 053	.78 817	.21 183	.06 947	.28 130	27
34	.71 891	.93 046	.78 845	.21 155	.06 954	.28 109	26
35	9.71 911	9.93 038	9.78 874	0.21 126	0.06 962	0.28 089	**25**
36	.71 932	.93 030	.78 902	.21 098	.06 970	.28 068	24
37	.71 952	.93 022	.78 930	.21 070	.06 978	.28 048	23
38	.71 973	.93 014	.78 959	.21 041	.06 986	.28 027	22
39	.71 994	.93 007	.78 987	.21 013	.06 993	.28 006	21
40	9.72 014	9.92 999	9.79 015	0.20 985	0.07 001	0.27 986	**20**
41	.72 034	.92 991	.79 043	.20 957	.07 009	.27 966	19
42	.72 055	.92 983	.79 072	.20 928	.07 017	.27 945	18
43	.72 075	.92 976	.79 100	.20 900	.07 024	.27 925	17
44	.72 096	.92 968	.79 128	.20 872	.07 032	.27 904	16
45	9.72 116	9.92 960	9.79 156	0.20 844	0.07 040	0.27 884	**15**
46	.72 137	.92 952	.79 185	.20 815	.07 048	.27 863	14
47	.72 157	.92 944	.79 213	.20 787	.07 056	.27 843	13
48	.72 177	.92 936	.79 241	.20 759	.07 064	.27 823	12
49	.72 198	.92 929	.79 269	.20 731	.07 071	.27 802	11
50	9.72 218	9.92 921	9.79 297	0.20 703	0.07 079	0.27 782	**10**
51	.72 238	.92 913	.79 326	.20 674	.07 087	.27 762	9
52	.72 259	.92 905	.79 354	.20 646	.07 095	.27 741	8
53	.72 279	.92 897	.79 382	.20 618	.07 103	.27 721	7
54	.72 299	.92 889	.79 410	.20 590	.07 111	.27 701	6
55	9.72 320	9.92 881	9.79 438	0.20 562	0.07 119	0.27 680	**5**
56	.72 340	.92 874	.79 466	.20 534	.07 126	.27 660	4
57	.72 360	.92 866	.79 495	.20 505	.07 134	.27 640	3
58	.72 381	.92 858	.79 523	.20 477	.07 142	.27 619	2
59	.72 401	.92 850	.79 551	.20 449	.07 150	.27 599	1
60	9.72 421	9.92 842	9.79 579	0.20 421	0.07 158	0.27 579	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

121° (301°) (238°) 58°

32° (212°) (327°) **147°**

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.72 421	9.92 842	9.79 579	0.20 421	0.07 158	0.27 579	**60**
1	.72 441	.92 834	.79 607	.20 393	.07 166	.27 559	59
2	.72 461	.92 826	.79 635	.20 365	.07 174	.27 539	58
3	.72 482	.92 818	.79 663	.20 337	.07 182	.27 518	57
4	.72 502	.92 810	.79 691	.20 309	.07 190	.27 498	56
5	9.72 522	9.92 803	9.79 719	0.20 281	0.07 197	0.27 478	**55**
6	.72 542	.92 795	.79 747	.20 253	.07 205	.27 458	54
7	.72 562	.92 787	.79 776	.20 224	.07 213	.27 438	53
8	.72 582	.92 779	.79 804	.20 196	.07 221	.27 418	52
9	.72 602	.92 771	.79 832	.20 168	.07 229	.27 398	51
10	9.72 622	9.92 763	9.79 860	0.20 140	0.07 237	0.27 378	**50**
11	.72 643	.92 755	.79 888	.20 112	.07 245	.27 357	49
12	.72 663	.92 747	.79 916	.20 084	.07 253	.27 337	48
13	.72 683	.92 739	.79 944	.20 056	.07 261	.27 317	47
14	.72 703	.92 731	.79 972	.20 028	.07 269	.27 297	46
15	9.72 723	9.92 723	9.80 000	0.20 000	0.07 277	0.27 277	**45**
16	.72 743	.92 715	.80 028	.19 972	.07 285	.27 257	44
17	.72 763	.92 707	.80 056	.19 944	.07 293	.27 237	43
18	.72 783	.92 699	.80 084	.19 916	.07 301	.27 217	42
19	.72 803	.92 691	.80 112	.19 888	.07 309	.27 197	41
20	9.72 823	9.92 683	9.80 140	0.19 860	0.07 317	0.27 177	**40**
21	.72 843	.92 675	.80 168	.19 832	.07 325	.27 157	39
22	.72 863	.92 667	.80 195	.19 805	.07 333	.27 137	38
23	.72 883	.92 659	.80 223	.19 777	.07 341	.27 117	37
24	.72 902	.92 651	.80 251	.19 749	.07 349	.27 098	36
25	9.72 922	9.92 643	9.80 279	0.19 721	0.07 357	0.27 078	**35**
26	.72 942	.92 635	.80 307	.19 693	.07 365	.27 058	34
27	.72 962	.92 627	.80 335	.19 665	.07 373	.27 038	33
28	.72 982	.92 619	.80 363	.19 637	.07 381	.27 018	32
29	.73 002	.92 611	.80 391	.19 609	.07 389	.26 998	31
30	9.73 022	0.92 603	9.80 419	0.19 581	0.07 397	0.26 978	**30**
31	.73 041	.92 595	.80 447	.19 553	.07 405	.26 959	29
32	.73 061	.92 587	.80 474	.19 526	.07 413	.26 939	28
33	.73 081	.92 579	.80 502	.19 498	.07 421	.26 919	27
34	.73 101	.92 571	.80 530	.19 470	.07 429	.26 899	26
35	9.73 121	9.92 563	9.80 558	0.19 442	0.07 437	0.26 879	**25**
36	.73 140	.92 555	.80 586	.19 414	.07 445	.26 860	24
37	.73 160	.92 546	.80 614	.19 386	.07 454	.26 840	23
38	.73 180	.92 538	.80 642	.19 358	.07 462	.26 820	22
39	.73 200	.92 530	.80 669	.19 331	.07 470	.26 800	21
40	9.73 219	9.92 522	9.80 697	0.19 303	0.07 478	0.26 781	**20**
41	.73 239	.92 514	.80 725	.19 275	.07 486	.26 761	19
42	.73 259	.92 506	.80 753	.19 247	.07 494	.26 741	18
43	.73 278	.92 498	.80 781	.19 219	.07 502	.26 722	17
44	.73 298	.92 490	.80 808	.19 192	.07 510	.26 702	16
45	9.73 318	9.92 482	9.80 836	0.19 164	0.07 518	0.26 682	**15**
46	.73 337	.92 473	.80 864	.19 136	.07 527	.26 663	14
47	.73 357	.92 465	.80 892	.19 108	.07 535	.26 643	13
48	.73 377	.92 457	.80 919	.19 081	.07 543	.26 623	12
49	.73 396	.92 449	.80 947	.19 053	.07 551	.26 604	11
50	9.73 416	9.92 441	9.80 975	0.19 025	0.07 559	0.26 584	**10**
51	.73 435	.92 433	.81 003	.18 997	.07 567	.26 565	9
52	.73 455	.92 425	.81 030	.18 970	.07 575	.26 545	8
53	.73 474	.92 416	.81 058	.18 942	.07 584	.26 526	7
54	.73 494	.92 408	.81 086	.18 914	.07 592	.26 506	6
55	9.73 513	9.92 400	9.81 113	0.18 887	0.07 600	0.26 487	**5**
56	.73 533	.92 392	.81 141	.18 859	.07 608	.26 467	4
57	.73 552	.92 384	.81 169	.18 831	.07 616	.26 448	3
58	.73 572	.92 376	.81 196	.18 804	.07 624	.26 428	2
59	.73 591	.92 367	.81 224	.18 776	.07 633	.26 409	1
60	9.73 611	9.92 359	9.81 252	0.18 748	0.07 641	0.26 389	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

122° (302°) (237°) **57°**

33° (213°) (326°) **146°**

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.73 611	9.92 359	9.81 252	0.18 748	0.07 641	0.26 389	**60**
1	.73 630	.92 351	.81 279	.18 721	.07 649	.26 370	59
2	.73 650	.92 343	.81 307	.18 693	.07 657	.26 350	58
3	.73 669	.92 335	.81 335	.18 665	.07 665	.26 331	57
4	.73 689	.92 326	.81 362	.18 638	.07 674	.26 311	56
5	9.73 708	9.92 318	9.81 390	0.18 610	0.07 682	0.26 292	**55**
6	.73 727	.92 310	.81 418	.18 582	.07 690	.26 273	54
7	.73 747	.92 302	.81 445	.18 555	.07 698	.26 253	53
8	.73 766	.92 293	.81 473	.18 527	.07 707	.26 234	52
9	.73 785	.92 285	.81 500	.18 500	.07 715	.26 215	51
10	9.73 805	9.92 277	9.81 528	0.18 472	0.07 723	0.26 195	**50**
11	.73 824	.92 269	.81 556	.18 444	.07 731	.26 176	49
12	.73 843	.92 260	.81 583	.18 417	.07 740	.26 157	48
13	.73 863	.92 252	.81 611	.18 389	.07 748	.26 137	47
14	.73 882	.92 244	.81 638	.18 362	.07 756	.26 118	46
15	9.73 901	9.92 235	9.81 666	0.18 334	0.07 765	0.26 099	**45**
16	.73 921	.92 227	.81 693	.18 307	.07 773	.26 079	44
17	.73 940	.92 219	.81 721	.18 279	.07 781	.26 060	43
18	.73 959	.92 211	.81 748	.18 252	.07 789	.26 041	42
19	.73 978	.92 202	.81 776	.18 224	.07 798	.26 022	41
20	9.73 997	9.92 194	9.81 803	0.18 197	0.07 806	0.26 003	**40**
21	.74 017	.92 186	.81 831	.18 169	.07 814	.25 983	39
22	.74 036	.92 177	.81 858	.18 142	.07 823	.25 964	38
23	.74 055	.92 169	.81 886	.18 114	.07 831	.25 945	37
24	.74 074	.92 161	.81 913	.18 087	.07 839	.25 926	36
25	9.74 093	9.92 152	9.81 941	0.18 059	0.07 848	0.25 907	**35**
26	.74 113	.92 144	.81 968	.18 032	.07 856	.25 887	34
27	.74 132	.92 136	.81 996	.18 004	.07 864	.25 868	33
28	.74 151	.92 127	.82 023	.17 977	.07 873	.25 849	32
29	.74 170	.92 119	.82 051	.17 949	.07 881	.25 830	31
30	9.74 189	9.92 111	9.82 078	0.17 922	0.07 889	0.25 811	**30**
31	.74 208	.92 102	.82 106	.17 894	.07 898	.25 792	29
32	.74 227	.92 094	.82 133	.17 867	.07 906	.25 773	28
33	.74 246	.92 086	.82 161	.17 839	.07 914	.25 754	27
34	.74 265	.92 077	.82 188	.17 812	.07 923	.25 735	26
35	9.74 284	9.92 069	9.82 215	0.17 785	0.07 931	0.25 716	**25**
36	.74 303	.92 060	.82 243	.17 757	.07 940	.25 697	24
37	.74 322	.92 052	.82 270	.17 730	.07 948	.25 678	23
38	.74 341	.92 044	.82 298	.17 702	.07 956	.25 659	22
39	.74 360	.92 035	.82 325	.17 675	.07 965	.25 640	21
40	9.74 379	9.92 027	9.82 352	0.17 648	0.07 973	0.25 621	**20**
41	.74 398	.92 018	.82 380	.17 620	.07 982	.25 602	19
42	.74 417	.92 010	.82 407	.17 593	.07 990	.25 583	18
43	.74 436	.92 002	.82 435	.17 565	.07 998	.25 564	17
44	.74 455	.91 993	.82 462	.17 538	.08 007	.25 545	16
45	9.74 474	9.91 985	9.82 489	0.17 511	0.08 015	0.25 526	**15**
46	.74 493	.91 976	.82 517	.17 483	.08 024	.25 507	14
47	.74 512	.91 968	.82 544	.17 456	.08 032	.25 488	13
48	.74 531	.91 959	.82 571	.17 429	.08 041	.25 469	12
49	.74 549	.91 951	.82 599	.17 401	.08 049	.25 451	11
50	9.74 568	9.91 942	9.82 626	0.17 374	0.08 058	0.25 432	**10**
51	.74 587	.91 934	.82 653	.17 347	.08 066	.25 413	9
52	.74 606	.91 925	.82 681	.17 319	.08 075	.25 394	8
53	.74 625	.91 917	.82 708	.17 292	.08 083	.25 375	7
54	.74 644	.91 908	.82 735	.17 265	.08 092	.25 356	6
55	9.74 662	9.91 900	9.82 762	0.17 238	0.08 100	0.25 338	**5**
56	.74 681	.91 891	.82 790	.17 210	.08 109	.25 319	4
57	.74 700	.91 883	.82 817	.17 183	.08 117	.25 300	3
58	.74 719	.91 874	.82 844	.17 156	.08 126	.25 281	2
59	.74 737	.91 866	.82 871	.17 129	.08 134	.25 263	1
60	9.74 756	9.91 857	9.82 899	0.17 101	0.08 143	0.25 244	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

123° (303°) (236°) **56°**

34° (214°) | (325°) **145°**

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.74 756	9.91 857	9.82 899	0.17 101	0.08 143	0.25 244	**60**
1	.74 775	.91 849	.82 926	.17 074	.08 151	.25 225	59
2	.74 794	.91 840	.82 953	.17 047	.08 160	.25 206	58
3	.74 812	.91 832	.82 980	.17 020	.08 168	.25 188	57
4	.74 831	.91 823	.83 008	.16 992	.08 177	.25 169	56
5	9.74 850	9.91 815	9.83 035	0.16 965	0.08 185	0.25 150	**55**
6	.74 868	.91 806	.83 062	.16 938	.08 194	.25 132	54
7	.74 887	.91 798	.83 089	.16 911	.08 202	.25 113	53
8	.74 906	.91 789	.83 117	.16 883	.08 211	.25 094	52
9	.74 924	.91 781	.83 144	.16 856	.08 219	.25 076	51
10	9.74 943	9.91 772	9.83 171	0.16 829	0.08 228	0.25 057	**50**
11	.74 961	.91 763	.83 198	.16 802	.08 237	.25 039	49
12	.74 980	.91 755	.83 225	.16 775	.08 245	.25 020	48
13	.74 999	.91 746	.83 252	.16 748	.08 254	.25 001	47
14	.75 017	.91 738	.83 280	.16 720	.08 262	.24 983	46
15	9.75 036	9.91 729	9.83 307	0.16 693	0.08 271	0.24 964	**45**
16	.75 054	.91 720	.83 334	.16 666	.08 280	.24 946	44
17	.75 073	.91 712	.83 361	.16 639	.08 288	.24 927	43
18	.75 091	.91 703	.83 388	.16 612	.08 297	.24 909	42
19	.75 110	.91 695	.83 415	.16 585	.08 305	.24 890	41
20	9.75 128	9.91 686	9.83 442	0.16 558	0.08 314	0.24 872	**40**
21	.75 147	.91 677	.83 470	.16 530	.08 323	.24 853	39
22	.75 165	.91 669	.83 497	.16 503	.08 331	.24 835	38
23	.75 184	.91 660	.83 524	.16 476	.08 340	.24 816	37
24	.75 202	.91 651	.83 551	.16 449	.08 349	.24 798	36
25	9.75 221	9.91 643	9.83 578	0.16 422	0.08 357	0.24 779	**35**
26	.75 239	.91 634	.83 605	.16 395	.08 366	.24 761	34
27	.75 258	.91 625	.83 632	.16 368	.08 375	.24 742	33
28	.75 276	.91 617	.83 659	.16 341	.08 383	.24 724	32
29	.75 294	.91 608	.83 686	.16 314	.08 392	.24 706	31
30	9.75 313	9.91 599	9.83 713	0.16 287	0.08 401	0.24 687	**30**
31	.75 331	.91 591	.83 740	.16 260	.08 409	.24 669	29
32	.75 350	.91 582	.83 768	.16 232	.08 418	.24 650	28
33	.75 368	.91 573	.83 795	.16 205	.08 427	.24 632	27
34	.75 386	.91 565	.83 822	.16 178	.08 435	.24 614	26
35	9.75 405	9.91 556	9.83 849	0.16 151	0.08 444	0.24 595	**25**
36	.75 423	.91 547	.83 876	.16 124	.08 453	.24 577	24
37	.75 441	.91 538	.83 903	.16 097	.08 462	.24 559	23
38	.75 459	.91 530	.83 930	.16 070	.08 470	.24 541	22
39	.75 478	.91 521	.83 957	.16 043	.08 479	.24 522	21
40	9.75 496	9.91 512	9.83 984	0.16 016	0.08 488	0.24 504	**20**
41	.75 514	.91 504	.84 011	.15 989	.08 496	.24 486	19
42	.75 533	.91 495	.84 038	.15 962	.08 505	.24 467	18
43	.75 551	.91 486	.84 065	.15 935	.08 514	.24 449	17
44	.75 569	.91 477	.84 092	.15 908	.08 523	.24 431	16
45	9.75 587	9.91 469	9.84 119	0.15 881	0.08 531	0.24 413	**15**
46	.75 605	.91 460	.84 146	.15 854	.08 540	.24 395	14
47	.75 624	.91 451	.84 173	.15 827	.08 549	.24 376	13
48	.75 642	.91 442	.84 200	.15 800	.08 558	.24 358	12
49	.75 660	.91 433	.84 227	.15 773	.08 567	.24 340	11
50	9.75 678	9.91 425	9.84 254	0.15 746	0.08 575	0.24 322	**10**
51	.75 696	.91 416	.84 280	.15 720	.08 584	.24 304	9
52	.75 714	.91 407	.84 307	.15 693	.08 593	.24 286	8
53	.75 733	.91 398	.84 334	.15 666	.08 602	.24 267	7
54	.75 751	.91 389	.84 361	.15 639	.08 611	.24 249	6
55	9.75 769	9.91 381	9.84 388	0.15 612	0.08 619	0.24 231	**5**
56	.75 787	.91 372	.84 415	.15 585	.08 628	.24 213	4
57	.75 805	.91 363	.84 442	.15 558	.08 637	.24 195	3
58	.75 823	.91 354	.84 469	.15 531	.08 646	.24 177	2
59	.75 841	.91 345	.84 496	.15 504	.08 655	.24 159	1
60	9.75 859	9.91 336	9.84 523	0.15 477	0.08 664	0.24 141	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

124° (304°) | (235°) **55°**

35° (215°) (324°) **144°**

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.75 859	9.91 336	9.84 523	0.15 477	0.08 664	0.24 141	**60**
1	.75 877	.91 328	.84 550	.15 450	.08 672	.24 123	59
2	.75 895	.91 319	.84 576	.15 424	.08 681	.24 105	58
3	.75 913	.91 310	.84 603	.15 397	.08 690	.24 087	57
4	.75 931	.91 301	.84 630	.15 370	.08 699	.24 069	56
5	9.75 949	9.91 292	9.84 657	0.15 343	0.08 708	0.24 051	**55**
6	.75 967	.91 283	.84 684	.15 316	.08 717	.24 033	54
7	.75 985	.91 274	.84 711	.15 289	.08 726	.24 015	53
8	.76 003	.91 266	.84 738	.15 262	.08 734	.23 997	52
9	.76 021	.91 257	.84 764	.15 236	.08 743	.23 979	51
10	9.76 039	9.91 248	9.84 791	0.15 209	0.08 752	0.23 961	**50**
11	.76 057	.91 239	.84 818	.15 182	.08 761	.23 943	49
12	.76 075	.91 230	.84 845	.15 155	.08 770	.23 925	48
13	.76 093	.91 221	.84 872	.15 128	.08 779	.23 907	47
14	.76 111	.91 212	.84 899	.15 101	.08 788	.23 889	46
15	9.76 129	9.91 203	9.84 925	0.15 075	0.08 797	0.23 871	**45**
16	.76 146	.91 194	.84 952	.15 048	.08 806	.23 854	44
17	.76 164	.91 185	.84 979	.15 021	.08 815	.23 836	43
18	.76 182	.91 176	.85 006	.14 994	.08 824	.23 818	42
19	.76 200	.91 167	.85 033	.14 967	.08 833	.23 800	41
20	9.76 218	9.91 158	9.85 059	0.14 941	0.08 842	0.23 782	**40**
21	.76 236	.91 149	.85 086	.14 914	.08 851	.23 764	39
22	.76 253	.91 141	.85 113	.14 887	.08 859	.23 747	38
23	.76 271	.91 132	.85 140	.14 860	.08 868	.23 729	37
24	.76 289	.91 123	.85 166	.14 834	.08 877	.23 711	36
25	9.76 307	9.91 114	9.85 193	0.14 807	0.08 886	0.23 693	**35**
26	.76 324	.91 105	.85 220	.14 780	.08 895	.23 676	34
27	.76 342	.91 096	.85 247	.14 753	.08 904	.23 658	33
28	.76 360	.91 087	.85 273	.14 727	.08 913	.23 640	32
29	.76 378	.91 078	.85 300	.14 700	.08 922	.23 622	31
30	9.76 395	9.91 069	9.85 327	0.14 673	0.08 931	0.23 605	**30**
31	.76 413	.91 060	.85 354	.14 646	.08 940	.23 587	29
32	.76 431	.91 051	.85 380	.14 620	.08 949	.23 569	28
33	.76 448	.91 042	.85 407	.14 593	.08 958	.23 552	27
34	.76 466	.91 033	.85 434	.14 566	.08 967	.23 534	26
35	9.76 484	9.91 023	9.85 460	0.14 540	0.08 977	0.23 516	**25**
36	.76 501	.91 014	.85 487	.14 513	.08 986	.23 499	24
37	.76 519	.91 005	.85 514	.14 486	.08 995	.23 481	23
38	.76 537	.90 996	.85 540	.14 460	.09 004	.23 463	22
39	.76 554	.90 987	.85 567	.14 433	.09 013	.23 446	21
40	9.76 572	9.90 978	9.85 594	0.14 406	0.09 022	0.23 428	**20**
41	.76 590	.90 969	.85 620	.14 380	.09 031	.23 410	19
42	.76 607	.90 960	.85 647	.14 353	.09 040	.23 393	18
43	.76 625	.90 951	.85 674	.14 326	.09 049	.23 375	17
44	.76 642	.90 942	.85 700	.14 300	.09 058	.23 358	16
45	9.76 660	9.90 933	9.85 727	0.14 273	0.09 067	0.23 340	**15**
46	.76 677	.90 924	.85 754	.14 246	.09 076	.23 323	14
47	.76 695	.90 915	.85 780	.14 220	.09 085	.23 305	13
48	.76 712	.90 906	.85 807	.14 193	.09 094	.23 288	12
49	.76 730	.90 896	.85 834	.14 166	.09 104	.23 270	11
50	9.76 747	9.90 887	9.85 860	0.14 140	0.09 113	0.23 253	**10**
51	.76 765	.90 878	.85 887	.14 113	.09 122	.23 235	9
52	.76 782	.90 869	.85 913	.14 087	.09 131	.23 218	8
53	.76 800	.90 860	.85 940	.14 060	.09 140	.23 200	7
54	.76 817	.90 851	.85 967	.14 033	.09 149	.23 183	6
55	9.76 835	9.90 842	9.85 993	0.14 007	0.09 158	0.23 165	**5**
56	.76 852	.90 832	.86 020	.13 980	.09 168	.23 148	4
57	.76 870	.90 823	.86 046	.13 954	.09 177	.23 130	3
58	.76 887	.90 814	.86 073	.13 927	.09 186	.23 113	2
59	.76 904	.90 805	.86 100	.13 900	.09 195	.23 096	1
60	9.76 922	9.90 796	9.86 126	0.13 874	0.09 204	0.23 078	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

125° (305°) (234°) **54°**

36° (216°) (323°) **143°**

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.76 922	9.90 796	9.86 126	0.13 874	0.09 204	0.23 078	**60**
1	.76 939	.90 787	.86 153	.13 847	.09 213	.23 061	59
2	.76 957	.90 777	.86 179	.13 821	.09 223	.23 043	58
3	.76 974	.90 768	.86 206	.13 794	.09 232	.23 026	57
4	.76 991	.90 759	.86 232	.13 768	.09 241	.23 009	56
5	9.77 009	9.90 750	9.86 259	0.13 741	0.09 250	0.22 991	**55**
6	.77 026	.90 741	.86 285	.13 715	.09 259	.22 974	54
7	.77 043	.90 731	.86 312	.13 688	.09 269	.22 957	53
8	.77 061	.90 722	.86 338	.13 662	.09 278	.22 939	52
9	.77 078	.90 713	.86 365	.13 635	.09 287	.22 922	51
10	9.77 095	9.90 704	9.86 392	0.13 608	0.09 296	0.22 905	**50**
11	.77 112	.90 694	.86 418	.13 582	.09 306	.22 888	49
12	.77 130	.90 685	.86 445	.13 555	.09 315	.22 870	48
13	.77 147	.90 676	.86 471	.13 529	.09 324	.22 853	47
14	.77 164	.90 667	.86 498	.13 502	.09 333	.22 836	46
15	9.77 181	9.90 657	9.86 524	0.13 476	0.09 343	0.22 819	**45**
16	.77 199	.90 648	.86 551	.13 449	.09 352	.22 801	44
17	.77 216	.90 639	.86 577	.13 423	.09 361	.22 784	43
18	.77 233	.90 630	.86 603	.13 397	.09 370	.22 767	42
19	.77 250	.90 620	.86 630	.13 370	.09 380	.22 750	41
20	9.77 268	9.90 611	9.86 656	0.13 344	0.09 389	0.22 732	**40**
21	.77 285	.90 602	.86 683	.13 317	.09 398	.22 715	39
22	.77 302	.90 592	.86 709	.13 291	.09 408	.22 698	38
23	.77 319	.90 583	.86 736	.13 264	.09 417	.22 681	37
24	.77 336	.90 574	.86 762	.13 238	.09 426	.22 664	36
25	9.77 353	9.90 565	9.86 789	0.13 211	0.09 435	0.22 647	**35**
26	.77 370	.90 555	.86 815	.13 185	.09 445	.22 630	34
27	.77 387	.90 546	.86 842	.13 158	.09 454	.22 613	33
28	.77 405	.90 537	.86 868	.13 132	.09 463	.22 595	32
29	.77 422	.90 527	.86 894	.13 106	.09 473	.22 578	31
30	9.77 439	9.90 518	9.86 921	0.13 079	0.09 482	0.22 561	**30**
31	.77 456	.90 509	.86 947	.13 053	.09 491	.22 544	29
32	.77 473	.90 499	.86 974	.13 026	.09 501	.22 527	28
33	.77 490	.90 490	.87 000	.13 000	.09 510	.22 510	27
34	.77 507	.90 480	.87 027	.12 973	.09 520	.22 493	26
35	9.77 524	9.90 471	9.87 053	0.12 947	0.09 529	0.22 476	**25**
36	.77 541	.90 462	.87 079	.12 921	.09 538	.22 459	24
37	.77 558	.90 452	.87 106	.12 894	.09 548	.22 442	23
38	.77 575	.90 443	.87 132	.12 868	.09 557	.22 425	22
39	.77 592	.90 434	.87 158	.12 842	.09 566	.22 408	21
40	9.77 609	9.90 424	9.87 185	0.12 815	0.09 576	0.22 391	**20**
41	.77 626	.90 415	.87 211	.12 789	.09 585	.22 374	19
42	.77 643	.90 405	.87 238	.12 762	.09 595	.22 357	18
43	.77 660	.90 396	.87 264	.12 736	.09 604	.22 340	17
44	.77 677	.90 386	.87 290	.12 710	.09 614	.22 323	16
45	9.77 694	9.90 377	9.87 317	0.12 683	0.09 623	0.22 306	**15**
46	.77 711	.90 368	.87 343	.12 657	.09 632	.22 289	14
47	.77 728	.90 358	.87 369	.12 631	.09 642	.22 272	13
48	.77 744	.90 349	.87 396	.12 604	.09 651	.22 256	12
49	.77 761	.90 339	.87 422	.12 578	.09 661	.22 239	11
50	9.77 778	9.90 330	9.87 448	0.12 552	0.09 670	0.22 222	**10**
51	.77 795	.90 320	.87 475	.12 525	.09 680	.22 205	9
52	.77 812	.90 311	.87 501	.12 499	.09 689	.22 188	8
53	.77 829	.90 301	.87 527	.12 473	.09 699	.22 171	7
54	.77 846	.90 292	.87 554	.12 446	.09 708	.22 154	6
55	9.77 862	9.90 282	9.87 580	0.12 420	0.09 718	0.22 138	**5**
56	.77 879	.90 273	.87 606	.12 394	.09 727	.22 121	4
57	.77 896	.90 263	.87 633	.12 367	.09 737	.22 104	3
58	.77 913	.90 254	.87 659	.12 341	.09 746	.22 087	2
59	.77 930	.90 244	.87 685	.12 315	.09 756	.22 070	1
60	9.77 946	9.90 235	9.87 711	0.12 289	0.09 765	0.22 054	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

126° (306°) (233°) **53°**

37° (217°) (322°) 142°

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.77 946	9.90 235	9.87 711	0.12 289	0.09 765	0.22 054	**60**
1	.77 963	.90 225	.87 738	.12 262	.09 775	.22 037	59
2	.77 980	.90 216	.87 764	.12 236	.09 784	.22 020	58
3	.77 997	.90 206	.87 790	.12 210	.09 794	.22 003	57
4	.78 013	.90 197	.87 817	.12 183	.09 803	.21 987	56
5	9.78 030	9.90 187	9.87 843	0.12 157	0.09 813	0.21 970	**55**
6	.78 047	.90 178	.87 869	.12 131	.09 822	.21 953	54
7	.78 063	.90 168	.87 895	.12 105	.09 832	.21 937	53
8	.78 080	.90 159	.87 922	.12 078	.09 841	.21 920	52
9	.78 097	.90 149	.87 948	.12 052	.09 851	.21 903	51
10	9.78 113	9.90 139	9.87 974	0.12 026	0.09 861	0.21 887	**50**
11	.78 130	.90 130	.88 000	.12 000	.09 870	.21 870	49
12	.78 147	.90 120	.88 027	.11 973	.09 880	.21 853	48
13	.78 163	.90 111	.88 053	.11 947	.09 889	.21 837	47
14	.78 180	.90 101	.88 079	.11 921	.09 899	.21 820	46
15	9.78 197	9.90 091	9.88 105	0.11 895	0.09 909	0.21 803	**45**
16	.78 213	.90 082	.88 131	.11 869	.09 918	.21 787	44
17	.78 230	.90 072	.88 158	.11 842	.09 928	.21 770	43
18	.78 246	.90 063	.88 184	.11 816	.09 937	.21 754	42
19	.78 263	.90 053	.88 210	.11 790	.09 947	.21 737	41
20	9.78 280	9.90 043	9.88 236	0.11 764	0.09 957	0.21 720	**40**
21	.78 296	.90 034	.88 262	.11 738	.09 966	.21 704	39
22	.78 313	.90 024	.88 289	.11 711	.09 976	.21 687	38
23	.78 329	.90 014	.88 315	.11 685	.09 986	.21 671	37
24	.78 346	.90 005	.88 341	.11 659	.09 995	.21 654	36
25	9.78 362	9.89 995	9.88 367	0.11 633	0.10 005	0.21 638	**35**
26	.78 379	.89 985	.88 393	.11 607	.10 015	.21 621	34
27	.78 395	.89 976	.88 420	.11 580	.10 024	.21 605	33
28	.78 412	.89 966	.88 446	.11 554	.10 034	.21 588	32
29	.78 428	.89 956	.88 472	.11 528	.10 044	.21 572	31
30	9.78 445	9.89 947	9.88 498	0.11 502	0.10 053	0.21 555	**30**
31	.78 461	.89 937	.88 524	.11 476	.10 063	.21 539	29
32	.78 478	.89 927	.88 550	.11 450	.10 073	.21 522	28
33	.78 494	.89 918	.88 577	.11 423	.10 082	.21 506	27
34	.78 510	.89 908	.88 603	.11 397	.10 092	.21 490	26
35	9.78 527	9.89 898	9.88 629	0.11 371	0.10 102	0.21 473	**25**
36	.78 543	.89 888	.88 655	.11 345	.10 112	.21 457	24
37	.78 560	.89 879	.88 681	.11 319	.10 121	.21 440	23
38	.78 576	.89 869	.88 707	.11 293	.10 131	.21 424	22
39	.78 592	.89 859	.88 733	.11 267	.10 141	.21 408	21
40	9.78 609	9.89 849	9.88 759	0.11 241	0.10 151	0.21 391	**20**
41	.78 625	.89 840	.88 786	.11 214	.10 160	.21 375	19
42	.78 642	.89 830	.88 812	.11 188	.10 170	.21 358	18
43	.78 658	.89 820	.88 838	.11 162	.10 180	.21 342	17
44	.78 674	.89 810	.88 864	.11 136	.10 190	.21 326	16
45	9.78 691	9.89 801	9.88 890	0.11 110	0.10 199	0.21 309	**15**
46	.78 707	.89 791	.88 916	.11 084	.10 209	.21 293	14
47	.78 723	.89 781	.88 942	.11 058	.10 219	.21 277	13
48	.78 739	.89 771	.88 968	.11 032	.10 229	.21 261	12
49	.78 756	.89 761	.88 994	.11 006	.10 239	.21 244	11
50	9.78 772	9.89 752	9.89 020	0.10 980	0.10 248	0.21 228	**10**
51	.78 788	.89 742	.89 046	.10 954	.10 258	.21 212	9
52	.78 805	.89 732	.89 073	.10 927	.10 268	.21 195	8
53	.78 821	.89 722	.89 099	.10 901	.10 278	.21 179	7
54	.78 837	.89 712	.89 125	.10 875	.10 288	.21 163	6
55	9.78 853	9.89 702	9.89 151	0.10 849	0.10 298	0.21 147	**5**
56	.78 869	.89 693	.89 177	.10 823	.10 307	.21 131	4
57	.78 886	.89 683	.89 203	.10 797	.10 317	.21 114	3
58	.78 902	.89 673	.89 229	.10 771	.10 327	.21 098	2
59	.78 918	.89 663	.89 255	.10 745	.10 337	.21 082	1
60	9.78 934	9.89 653	9.89 281	0.10 719	0.10 347	0.21 066	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

127° (307°) (232°) 52°

38° (218°) (321°) **141°**

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.78 934	9.89 653	9.89 281	0.10 719	0.10 347	0.21 066	**60**
1	.78 950	.89 643	.89 307	.10 693	.10 357	.21 050	59
2	.78 967	.89 633	.89 333	.10 667	.10 367	.21 033	58
3	.78 983	.89 624	.89 359	.10 641	.10 376	.21 017	57
4	.78 999	.89 614	.89 385	.10 615	.10 386	.21 001	56
5	9.79 015	9.89 604	9.89 411	0.10 589	0.10 396	0.20 985	**55**
6	.79 031	.89 594	.89 437	.10 563	.10 406	.20 969	54
7	.79 047	.89 584	.89 463	.10 537	.10 416	.20 953	53
8	.79 063	.89 574	.89 489	.10 511	.10 426	.20 937	52
9	.79 079	.89 564	.89 515	.10 485	.10 436	.20 921	51
10	9.79 095	9.89 554	9.89 541	0.10 459	0.10 446	0.20 905	**50**
11	.79 111	.89 544	.89 567	.10 433	.10 456	.20 889	49
12	.79 128	.89 534	.89 593	.10 407	.10 466	.20 872	48
13	.79 144	.89 524	.89 619	.10 381	.10 476	.20 856	47
14	.79 160	.89 514	.89 645	.10 355	.10 486	.20 840	46
15	9.79 176	9.89 504	9.89 671	0.10 329	0.10 496	0.20 824	**45**
16	.79 192	.89 495	.89 697	.10 303	.10 505	.20 808	44
17	.79 208	.89 485	.89 723	.10 277	.10 515	.20 792	43
18	.79 224	.89 475	.89 749	.10 251	.10 525	.20 776	42
19	.79 240	.89 465	.89 775	.10 225	.10 535	.20 760	41
20	9.79 256	9.89 455	9.89 801	0.10 199	0.10 545	0.20 744	**40**
21	.79 272	.89 445	.89 827	.10 173	.10 555	.20 728	39
22	.79 288	.89 435	.89 853	.10 147	.10 565	.20 712	38
23	.79 304	.89 425	.89 879	.10 121	.10 575	.20 696	37
24	.79 319	.89 415	.89 905	.10 095	.10 585	.20 681	36
25	9.79 335	9.89 405	9.89 931	0.10 069	0.10 595	0.20 665	**35**
26	.79 351	.89 395	.89 957	.10 043	.10 605	.20 649	34
27	.79 367	.89 385	.89 983	.10 017	.10 615	.20 633	33
28	.79 383	.89 375	.90 009	.09 991	.10 625	.20 617	32
29	.79 399	.89 364	.90 035	.09 965	.10 636	.20 601	31
30	9.79 415	9.89 354	9.90 061	0.09 939	0.10 646	0.20 585	**30**
31	.79 431	.89 344	.90 086	.09 914	.10 656	.20 569	29
32	.79 447	.89 334	.90 112	.09 888	.10 666	.20 553	28
33	.79 463	.89 324	.90 138	.09 862	.10 676	.20 537	27
34	.79 478	.89 314	.90 164	.09 836	.10 686	.20 522	26
35	9.79 494	9.89 304	9.90 190	0.09 810	0.10 696	0.20 506	**25**
36	.79 510	.89 294	.90 216	.09 784	.10 706	.20 490	24
37	.79 526	.89 284	.90 242	.09 758	.10 716	.20 474	23
38	.79 542	.89 274	.90 268	.09 732	.10 726	.20 458	22
39	.79 558	.89 264	.90 294	.09 706	.10 736	.20 442	21
40	9.79 573	9.89 254	9.90 320	0.09 680	0.10 746	0.20 427	**20**
41	.79 589	.89 244	.90 346	.09 654	.10 756	.20 411	19
42	.79 605	.89 233	.90 371	.09 629	.10 767	.20 395	18
43	.79 621	.89 223	.90 397	.09 603	.10 777	.20 379	17
44	.79 636	.89 213	.90 423	.09 577	.10 787	.20 364	16
45	9.79 652	9.89 203	9.90 449	0.09 551	0.10 797	0.20 348	**15**
46	.79 668	.89 193	.90 475	.09 525	.10 807	.20 332	14
47	.79 684	.89 183	.90 501	.09 499	.10 817	.20 316	13
48	.79 699	.89 173	.90 527	.09 473	.10 827	.20 301	12
49	.79 715	.89 162	.90 553	.09 447	.10 838	.20 285	11
50	9.79 731	9.89 152	9.90 578	0.09 422	0.10 848	0.20 269	**10**
51	.79 746	.89 142	.90 604	.09 396	.10 858	.20 254	9
52	.79 762	.89 132	.90 630	.09 370	.10 868	.20 238	8
53	.79 778	.89 122	.90 656	.09 344	.10 878	.20 222	7
54	.79 793	.89 112	.90 682	.09 318	.10 888	.20 207	6
55	9.79 809	9.89 101	9.90 708	0.09 292	0.10 899	0.20 191	**5**
56	.79 825	.89 091	.90 734	.09 266	.10 909	.20 175	4
57	.79 840	.89 081	.90 759	.09 241	.10 919	.20 160	3
58	.79 856	.89 071	.90 785	.09 215	.10 929	.20 144	2
59	.79 872	.89 060	.90 811	.09 189	.10 940	.20 128	1
60	9.79 887	9.89 050	9.90 837	0.09 163	0.10 950	0.20 113	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

128° (308°) (231°) **51°**

39° (219°) (320°) **140°**

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.79 887	9.89 050	9.90 837	0.09 163	0.10 950	0.20 113	**60**
1	.79 903	.89 040	.90 863	.09 137	.10 960	.20 097	59
2	.79 918	.89 030	.90 889	.09 111	.10 970	.20 082	58
3	.79 934	.89 020	.90 914	.09 086	.10 980	.20 066	57
4	.79 950	.89 009	.90 940	.09 060	.10 991	.20 050	56
5	9.79 965	9.88 999	9.90 966	0.09 034	0.11 001	0.20 035	**55**
6	.79 981	.88 989	.90 992	.09 008	.11 011	.20 019	54
7	.79 996	.88 978	.91 018	.08 982	.11 022	.20 004	53
8	.80 012	.88 968	.91 043	.08 957	.11 032	.19 988	52
9	.80 027	.88 958	.91 069	.08 931	.11 042	.19 973	51
10	9.80 043	9.88 948	9.91 095	0.08 905	0.11 052	0.19 957	**50**
11	.80 058	.88 937	.91 121	.08 879	.11 063	.19 942	49
12	.80 074	.88 927	.91 147	.08 853	.11 073	.19 926	48
13	.80 089	.88 917	.91 172	.08 828	.11 083	.19 911	47
14	.80 105	.88 906	.91 198	.08 802	.11 094	.19 895	46
15	9.80 120	9.88 896	9.91 224	0.08 776	0.11 104	0.19 880	**45**
16	.80 136	.88 886	.91 250	.08 750	.11 114	.19 864	44
17	.80 151	.88 875	.91 276	.08 724	.11 125	.19 849	43
18	.80 166	.88 865	.91 301	.08 699	.11 135	.19 834	42
19	.80 182	.88 855	.91 327	.08 673	.11 145	.19 818	41
20	9.80 197	9.88 844	9.91 353	0.08 647	0.11 156	0.19 803	**40**
21	.80 213	.88 834	.91 379	.08 621	.11 166	.19 787	39
22	.80 228	.88 824	.91 404	.08 596	.11 176	.19 772	38
23	.80 244	.88 813	.91 430	.08 570	.11 187	.19 756	37
24	.80 259	.88 803	.91 456	.08 544	.11 197	.19 741	36
25	9.80 274	9.88 793	9.91 482	0.08 518	0.11 207	0.19 726	**35**
26	.80 290	.88 782	.91 507	.08 493	.11 218	.19 710	34
27	.80 305	.88 772	.91 533	.08 467	.11 228	.19 695	33
28	.80 320	.88 761	.91 559	.08 441	.11 239	.19 680	32
29	.80 336	.88 751	.91 585	.08 415	.11 249	.19 664	31
30	9.80 351	9.88 741	9.91 610	0.08 390	0.11 259	0.19 649	**30**
31	.80 366	.88 730	.91 636	.08 364	.11 270	.19 634	29
32	.80 382	.88 720	.91 662	.08 338	.11 280	.19 618	28
33	.80 397	.88 709	.91 688	.08 312	.11 291	.19 603	27
34	.80 412	.88 699	.91 713	.08 287	.11 301	.19 588	26
35	9.80 428	9.88 688	9.91 739	0.08 261	0.11 312	0.19 572	**25**
36	.80 443	.88 678	.91 765	.08 235	.11 322	.19 557	24
37	.80 458	.88 668	.91 791	.08 209	.11 332	.19 542	23
38	.80 473	.88 657	.91 816	.08 184	.11 343	.19 527	22
39	.80 489	.88 647	.91 842	.08 158	.11 353	.19 511	21
40	9.80 504	9.88 636	9.91 868	0.08 132	0.11 364	0.19 496	**20**
41	.80 519	.88 626	.91 893	.08 107	.11 374	.19 481	19
42	.80 534	.88 615	.91 919	.08 081	.11 385	.19 466	18
43	.80 550	.88 605	.91 945	.08 055	.11 395	.19 450	17
44	.80 565	.88 594	.91 971	.08 029	.11 406	.19 435	16
45	9.80 580	9.88 584	9.91 996	0.08 004	0.11 416	0.19 420	**15**
46	.80 595	.88 573	.92 022	.07 978	.11 427	.19 405	14
47	.80 610	.88 563	.92 048	.07 952	.11 437	.19 390	13
48	.80 625	.88 552	.92 073	.07 927	.11 448	.19 375	12
49	.80 641	.88 542	.92 099	.07 901	.11 458	.19 359	11
50	9.80 656	9.88 531	9.92 125	0.07 875	0.11 469	0.19 344	**10**
51	.80 671	.88 521	.92 150	.07 850	.11 479	.19 329	9
52	.80 686	.88 510	.92 176	.07 824	.11 490	.19 314	8
53	.80 701	.88 499	.92 202	.07 798	.11 501	.19 299	7
54	.80 716	.88 489	.92 227	.07 773	.11 511	.19 284	6
55	9.80 731	9.88 478	9.92 253	0.07 747	0.11 522	0.19 269	**5**
56	.80 746	.88 468	.92 279	.07 721	.11 532	.19 254	4
57	.80 762	.88 457	.92 304	.07 696	.11 543	.19 238	3
58	.80 777	.88 447	.92 330	.07 670	.11 553	.19 223	2
59	.80 792	.88 436	.92 356	.07 644	.11 564	.19 208	1
60	9.80 807	9.88 425	9.92 381	0.07 619	0.11 575	0.19 193	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

129° (309°) (230°) **50°**

40° (220°) (319°) **139°**

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.80 807	9.88 425	9.92 381	0.07 619	0.11 575	0.19 193	**60**
1	.80 822	.88 415	.92 407	.07 593	.11 585	.19 178	59
2	.80 837	.88 404	.92 433	.07 567	.11 596	.19 163	58
3	.80 852	.88 394	.92 458	.07 542	.11 606	.19 148	57
4	.80 867	.88 383	.92 484	.07 516	.11 617	.19 133	56
5	9.80 882	9.88 372	9.92 510	0.07 490	0.11 628	0.19 118	**55**
6	.80 897	.88 362	.92 535	.07 465	.11 638	.19 103	54
7	.80 912	.88 351	.92 561	.07 439	.11 649	.19 088	53
8	.80 927	.88 340	.92 587	.07 413	.11 660	.19 073	52
9	.80 942	.88 330	.92 612	.07 388	.11 670	.19 058	51
10	9.80 957	9.88 319	9.92 638	0.07 362	0.11 681	0.19 043	**50**
11	.80 972	.88 308	.92 663	.07 337	.11 692	.19 028	49
12	.80 987	.88 298	.92 689	.07 311	.11 702	.19 013	48
13	.81 002	.88 287	.92 715	.07 285	.11 713	.18 998	47
14	.81 017	.88 276	.92 740	.07 260	.11 724	.18 983	46
15	9.81 032	9.88 266	9.92 766	0.07 234	0.11 734	0.18 968	**45**
16	.81 047	.88 255	.92 792	.07 208	.11 745	.18 953	44
17	.81 061	.88 244	.92 817	.07 183	.11 756	.18 939	43
18	.81 076	.88 234	.92 843	.07 157	.11 766	.18 924	42
19	.81 091	.88 223	.92 868	.07 132	.11 777	.18 909	41
20	9.81 106	9.88 212	9.92 894	0.07 106	0.11 788	0.18 894	**40**
21	.81 121	.88 201	.92 920	.07 080	.11 799	.18 879	39
22	.81 136	.88 191	.92 945	.07 055	.11 809	.18 864	38
23	.81 151	.88 180	.92 971	.07 029	.11 820	.18 849	37
24	.81 166	.88 169	.92 996	.07 004	.11 831	.18 834	36
25	9.81 180	9.88 158	9.93 022	0.06 978	0.11 842	0.18 820	**35**
26	.81 195	.88 148	.93 048	.06 952	.11 852	.18 805	34
27	.81 210	.88 137	.93 073	.06 927	.11 863	.18 790	33
28	.81 225	.88 126	.93 099	.06 901	.11 874	.18 775	32
29	.81 240	.88 115	.93 124	.06 876	.11 885	.18 760	31
30	9.81 254	9.88 105	9.93 150	0.06 850	0.11 895	0.18 746	**30**
31	.81 269	.88 094	.93 175	.06 825	.11 906	.18 731	29
32	.81 284	.88 083	.93 201	.06 799	.11 917	.18 716	28
33	.81 299	.88 072	.93 227	.06 773	.11 928	.18 701	27
34	.81 314	.88 061	.93 252	.06 748	.11 939	.18 686	26
35	9.81 328	9.88 051	9.93 278	0.06 722	0.11 949	0.18 672	**25**
36	.81 343	.88 040	.93 303	.06 697	.11 960	.18 657	24
37	.81 358	.88 029	.93 329	.06 671	.11 971	.18 642	23
38	.81 372	.88 018	.93 354	.06 646	.11 982	.18 628	22
39	.81 387	.88 007	.93 380	.06 620	.11 993	.18 613	21
40	9.81 402	9.87 996	9.93 406	0.06 594	0.12 004	0.18 598	**20**
41	.81 417	.87 985	.93 431	.06 569	.12 015	.18 583	19
42	.81 431	.87 975	.93 457	.06 543	.12 025	.18 569	18
43	.81 446	.87 964	.92 482	.06 518	.12 036	.18 554	17
44	.81 461	.87 953	.93 508	.06 492	.12 047	.18 539	16
45	9.81 475	9.87 942	9.93 533	0.06 467	0.12 058	0.18 525	**15**
46	.81 490	.87 931	.93 559	.06 441	.12 069	.18 510	14
47	.81 505	.87 920	.93 584	.06 416	.12 080	.18 495	13
48	.81 519	.87 909	.93 610	.06 390	.12 091	.18 481	12
49	.81 534	.87 898	.93 636	.06 364	.12 102	.18 466	11
50	9.81 549	9.87 887	9.93 661	0.06 339	0.12 113	0.18 451	**10**
51	.81 563	.87 877	.93 687	.06 313	.12 123	.18 437	9
52	.81 578	.87 866	.93 712	.06 288	.12 134	.18 422	8
53	.81 592	.87 855	.93 738	.06 262	.12 145	.18 408	7
54	.81 607	.87 844	.93 763	.06 237	.12 156	.18 393	6
55	9.81 622	9.87 833	9.93 789	0.06 211	0.12 167	0.18 378	**5**
56	.81 636	.87 822	.93 814	.06 186	.12 178	.18 364	4
57	.81 651	.87 811	.93 840	.06 160	.12 189	.18 349	3
58	.81 665	.87 800	.93 865	.06 135	.12 200	.18 335	2
59	.81 680	.87 789	.93 891	.06 109	.12 211	.18 320	1
60	9.81 694	9.87 778	9.93 916	0.06 084	0.12 222	.18 306	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

130° (310°) (229°) **49°**

41° (221°) (318°) **138°**

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.81 694	9.87 778	9.93 916	0.06 084	0.12 222	0.18 306	**60**
1	.81 709	.87 767	.93 942	.06 058	.12 233	.18 291	59
2	.81 723	.87 756	.93 967	.06 033	.12 244	.18 277	58
3	.81 738	.87 745	.93 993	.06 007	.12 255	.18 262	57
4	.81 752	.87 734	.94 018	.05 982	.12 266	.18 248	56
5	9.81 767	9.87 723	9.94 044	0.05 956	0.12 277	0.18 233	**55**
6	.81 781	.87 712	.94 069	.05 931	.12 288	.18 219	54
7	.81 796	.87 701	.94 095	.05 905	.12 299	.18 204	53
8	.81 810	.87 690	.94 120	.05 880	.12 310	.18 190	52
9	.81 825	.87 679	.94 146	.05 854	.12 321	.18 175	51
10	9.81 839	9.87 668	9.94 171	0.05 829	0.12 332	0.18 161	**50**
11	.81 854	.87 657	.94 197	.05 803	.12 343	.18 146	49
12	.81 868	.87 646	.94 222	.05 778	.12 354	.18 132	48
13	.81 882	.87 635	.94 248	.05 752	.12 365	.18 118	47
14	.81 897	.87 624	.94 273	.05 727	.12 376	.18 103	46
15	9.81 911	9.87 613	9.94 299	0.05 701	0.12 387	0.18 089	**45**
16	.81 926	.87 601	.94 324	.05 676	.12 399	.18 074	44
17	.81 940	.87 590	.94 350	.05 650	.12 410	.18 060	43
18	.81 955	.87 579	.94 375	.05 625	.12 421	.18 045	42
19	.81 969	.87 568	.94 401	.05 599	.12 432	.18 031	41
20	9.81 983	9.87 557	9.94 426	0.05 574	0.12 443	0.18 017	**40**
21	.81 998	.87 546	.94 452	.05 548	.12 454	.18 002	39
22	.82 012	.87 535	.94 477	.05 523	.12 465	.17 988	38
23	.82 026	.87 524	.94 503	.05 497	.12 476	.17 974	37
24	.82 041	.87 513	.94 528	.05 472	.12 487	.17 959	36
25	9.82 055	9.87 501	9.94 554	0.05 446	0.12 499	0.17 945	**35**
26	.82 069	.87 490	.94 579	.05 421	.12 510	.17 931	34
27	.82 084	.87 479	.94 604	.05 396	.12 521	.17 916	33
28	.82 098	.87 468	.94 630	.05 370	.12 532	.17 902	32
29	.82 112	.87 457	.94 655	.05 345	.12 543	.17 888	31
30	9.82 126	9.87 446	9.94 681	0.05 319	0.12 554	0.17 874	**30**
31	.82 141	.87 434	.94 706	.05 294	.12 566	.17 859	29
32	.82 155	.87 423	.94 732	.05 268	.12 577	.17 845	28
33	.82 169	.87 412	.94 757	.05 243	.12 588	.17 831	27
34	.82 184	.87 401	.94 783	.05 217	.12 599	.17 816	26
35	9.82 198	9.87 390	9.94 808	0.05 192	0.12 610	0.17 802	**25**
36	.82 212	.87 378	.94 834	.05 166	.12 622	.17 788	24
37	.82 226	.87 367	.94 859	.05 141	.12 633	.17 774	23
38	.82 240	.87 356	.94 884	.05 116	.12 644	.17 760	22
39	.82 255	.87 345	.94 910	.05 090	.12 655	.17 745	21
40	9.82 269	9.87 334	9.94 935	0.05 065	0.12 666	0.17 731	**20**
41	.82 283	.87 322	.94 961	.05 039	.12 678	.17 717	19
42	.82 297	.87 311	.94 986	.05 014	.12 689	.17 703	18
43	.82 311	.87 300	.95 012	.04 988	.12 700	.17 689	17
44	.82 326	.87 288	.95 037	.04 963	.12 712	.17 674	16
45	9.82 340	9.87 277	9.95 062	0.04 938	0.12 723	0.17 660	**15**
46	.82 354	.87 266	.95 088	.04 912	.12 734	.17 646	14
47	.82 368	.87 255	.95 113	.04 887	.12 745	.17 632	13
48	.82 382	.87 243	.95 139	.04 861	.12 757	.17 618	12
49	.82 396	.87 232	.95 164	.04 836	.12 768	.17 604	11
50	9.82 410	9.87 221	9.95 190	0.04 810	0.12 779	0.17 590	**10**
51	.82 424	.87 209	.95 215	.04 785	.12 791	.17 576	9
52	.82 439	.87 198	.95 240	.04 760	.12 802	.17 561	8
53	.82 453	.87 187	.95 266	.04 734	.12 813	.17 547	7
54	.82 467	.87 175	.95 291	.04 709	.12 825	.17 533	6
55	9.82 481	9.87 164	9.95 317	0.04 683	0.12 836	0.17 519	**5**
56	.82 495	.87 153	.95 342	.04 658	.12 847	.17 505	4
57	.82 509	.87 141	.95 368	.04 632	.12 859	.17 491	3
58	.82 523	.87 130	.95 393	.04 607	.12 870	.17 477	2
59	.82 537	.87 119	.95 418	.04 582	.12 881	.17 463	1
60	9.82 551	9.87 107	9.95 444	0.04 556	0.12 893	0.17 449	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

131° (311°) (228°) **48°**

42° (222°) (317°) **137°**

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.82 551	9.87 107	9.95 444	0.04 556	0.12 893	0.17 449	**60**
1	.82 565	.87 096	.95 469	.04 531	.12 904	.17 435	59
2	.82 579	.87 085	.95 495	.04 505	.12 915	.17 421	58
3	.82 593	.87 073	.95 520	.04 480	.12 927	.17 407	57
4	.82 607	.87 062	.95 545	.04 455	.12 938	.17 393	56
5	9.82 621	9.87 050	9.95 571	0.04 429	0.12 950	0.17 379	**55**
6	.82 635	.87 039	.95 596	.04 404	.12 961	.17 365	54
7	.82 649	.87 028	.95 622	.04 378	.12 972	.17 351	53
8	.82 663	.87 016	.95 647	.04 353	.12 984	.17 337	52
9	.82 677	.87 005	.95 672	.04 328	.12 995	.17 323	51
10	9.82 691	9.86 993	9.95 698	0.04 302	0.13 007	0.17 309	**50**
11	.82 705	.86 982	.95 723	.04 277	.13 018	.17 295	49
12	.82 719	.86 970	.95 748	.04 252	.13 030	.17 281	48
13	.82 733	.86 959	.95 774	.04 226	.13 041	.17 267	47
14	.82 747	.86 947	.95 799	.04 201	.13 053	.17 253	46
15	9.82 761	9.86 936	9.95 825	0.04 175	0.13 064	0.17 239	**45**
16	.82 775	.86 924	.95 850	.04 150	.13 076	.17 225	44
17	.82 788	.86 913	.95 875	.04 125	.13 087	.17 212	43
18	.82 802	.86 902	.95 901	.04 099	.13 098	.17 198	42
19	.82 816	.86 890	.95 926	.04 074	.13 110	.17 184	41
20	9.82 830	9.86 879	9.95 952	0.04 048	0.13 121	0.17 170	**40**
21	.82 844	.86 867	.95 977	.04 023	.13 133	.17 156	39
22	.82 858	.86 855	.96 002	.03 998	.13 145	.17 142	38
23	.82 872	.86 844	.96 028	.03 972	.13 156	.17 128	37
24	.82 885	.86 832	.96 053	.03 947	.13 168	.17 115	36
25	9.82 899	9.86 821	9.96 078	0.03 922	0.13 179	0.17 101	**35**
26	.82 913	.86 809	.96 104	.03 896	.13 191	.17 087	34
27	.82 927	.86 798	.96 129	.03 871	.13 202	.17 073	33
28	.82 941	.86 786	.96 155	.03 845	.13 214	.17 059	32
29	.82 955	.86 775	.96 180	.03 820	.13 225	.17 045	31
30	9.82 968	9.86 763	9.96 205	0.03 795	0.13 237	0.17 032	**30**
31	.82 982	.86 752	.96 231	.03 769	.13 248	.17 018	29
32	.82 996	.86 740	.96 256	.03 744	.13 260	.17 004	28
33	.83 010	.86 728	.96 281	.03 719	.13 272	.16 990	27
34	.83 023	.86 717	.96 307	.03 693	.13 283	.16 977	26
35	9.83 037	9.86 705	9.96 332	0.03 668	0.13 295	0.16 963	**25**
36	.83 051	.86 694	.96 357	.03 643	.13 306	.16 949	24
37	.83 065	.86 682	.96 383	.03 617	.13 318	.16 935	23
38	.83 078	.86 670	.96 408	.03 592	.13 330	.16 922	22
39	.83 092	.86 659	.96 433	.03 567	.13 341	.16 908	21
40	9.83 106	9.86 647	9.96 459	0.03 541	0.13 353	0.16 894	**20**
41	.83 120	.86 635	.96 484	.03 516	.13 365	.16 880	19
42	.83 133	.86 624	.96 510	.03 490	.13 376	.16 867	18
43	.83 147	.86 612	.96 535	.03 465	.13 388	.16 853	17
44	.83 161	.86 600	.96 560	.03 440	.13 400	.16 839	16
45	9.83 174	9.86 589	9.96 586	0.03 414	0.13 411	0.16 826	**15**
46	.83 188	.86 577	.96 611	.03 389	.13 423	.16 812	14
47	.83 202	.86 565	.96 636	.03 364	.13 435	.16 798	13
48	.83 215	.86 554	.96 662	.03 338	.13 446	.16 785	12
49	.83 229	.86 542	.96 687	.03 313	.13 458	.16 771	11
50	9.83 242	9.86 530	9.96 712	0.03 288	0.13 470	0.16 758	**10**
51	.83 256	.86 518	.96 738	.03 262	.13 482	.16 744	9
52	.83 270	.86 507	.96 763	.03 237	.13 493	.16 730	8
53	.83 283	.86 495	.96 788	.03 212	.13 505	.16 717	7
54	.83 297	.86 483	.96 814	.03 186	.13 517	.16 703	6
55	9.83 310	9.86 472	9.96 839	0.03 161	0.13 528	0.16 690	**5**
56	.83 324	.86 460	.96 864	.03 136	.13 540	.16 676	4
57	.83 338	.86 448	.96 890	.03 110	.13 552	.16 662	3
58	.83 351	.86 436	.96 915	.03 085	.13 564	.16 649	2
59	.83 365	.86 425	.96 940	.03 060	.13 575	.16 635	1
60	9.83 378	9.86 413	9.96 966	0.03 034	0.13 587	0.16 622	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

132° (312°) (227°) **47°**

43° (223°) (316°) 136°

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.83 378	9.86 413	9.96 966	0.03 034	0.13 587	0.16 622	**60**
1	.83 392	.86 401	.96 991	.03 009	.13 599	.16 608	59
2	.83 405	.86 389	.97 016	.02 984	.13 611	.16 595	58
3	.83 419	.86 377	.97 042	.02 958	.13 623	.16 581	57
4	.83 432	.86 366	.97 067	.02 933	.13 634	.16 568	56
5	9.83 446	9.86 354	9.97 092	0.02 908	0.13 646	0.16 554	**55**
6	.83 459	.86 342	.97 118	.02 882	.13 658	.16 541	54
7	.83 473	.86 330	.97 143	.02 857	.13 670	.16 527	53
8	.83 486	.86 318	.97 168	.02 832	.13 682	.16 514	52
9	.83 500	.86 306	.97 193	.02 807	.13 694	.16 500	51
10	9.83 513	9.86 295	9.97 219	0.02 781	0.13 705	0.16 487	**50**
11	.83 527	.86 283	.97 244	.02 756	.13 717	.16 473	49
12	.83 540	.86 271	.97 269	.02 731	.13 729	.16 460	48
13	.83 554	.86 259	.97 295	.02 705	.13 741	.16 446	47
14	.83 567	.86 247	.97 320	.02 680	.13 753	.16 433	46
15	9.83 581	9.86 235	9.97 345	0.02 655	0.13 765	0.16 419	**45**
16	.83 594	.86 223	.97 371	.02 629	.13 777	.16 406	44
17	.83 608	.86 211	.97 396	.02 604	.13 789	.16 392	43
18	.83 621	.86 200	.97 421	.02 579	.13 800	.16 379	42
19	.83 634	.86 188	.97 447	.02 553	.13 812	.16 366	41
20	9.83 648	9.86 176	9.97 472	0.02 528	0.13 824	0.16 352	**40**
21	.83 661	.86 164	.97 497	.02 503	.13 836	.16 339	39
22	.83 674	.86 152	.97 523	.02 477	.13 848	.16 326	38
23	.83 688	.86 140	.97 548	.02 452	.13 860	.16 312	37
24	.83 701	.86 128	.97 573	.02 427	.13 872	.16 299	36
25	9.83 715	9.86 116	9.97 598	0.02 402	0.13 884	0.16 285	**35**
26	.83 728	.86 104	.97 624	.02 376	.13 896	.16 272	34
27	.83 741	.86 092	.97 649	.02 351	.13 908	.16 259	33
28	.83 755	.86 080	.97 674	.02 326	.13 920	.16 245	32
29	.83 768	.86 068	.97 700	.02 300	.13 932	.16 232	31
30	9.83 781	9.86 056	9.97 725	0.02 275	0.13 944	0.16 219	**30**
31	.83 795	.86 044	.97 750	.02 250	.13 956	.16 205	29
32	.83 808	.86 032	.97 776	.02 224	.13 968	.16 192	28
33	.83 821	.86 020	.97 801	.02 199	.13 980	.16 179	27
34	.83 834	.86 008	.97 826	.02 174	.13 992	.16 166	26
35	9.83 848	9.85 996	9.97 851	0.02 149	0.14 004	0.16 152	**25**
36	.83 861	.85 984	.97 877	.02 123	.14 016	.16 139	24
37	.83 874	.85 972	.97 902	.02 098	.14 028	.16 126	23
38	.83 887	.85 960	.97 927	.02 073	.14 040	.16 113	22
39	.83 901	.85 948	.97 953	.02 047	.14 052	.16 099	21
40	9.83 914	9.85 936	9.97 978	0.02 022	0.14 064	0.16 086	**20**
41	.83 927	.85 924	.98 003	.01 997	.14 076	.16 073	19
42	.83 940	.85 912	.98 029	.01 971	.14 088	.16 060	18
43	.83 954	.85 900	.98 054	.01 946	.14 100	.16 046	17
44	.83 967	.85 888	.98 079	.01 921	.14 112	.16 033	16
45	9.83 980	9.85 876	9.98 104	0.01 896	0.14 124	0.16 020	**15**
46	.83 993	.85 864	.98 130	.01 870	.14 136	.16 007	14
47	.84 006	.85 851	.98 155	.01 845	.14 149	.15 994	13
48	.84 020	.85 839	.98 180	.01 820	.14 161	.15 980	12
49	.84 033	.85 827	.98 206	.01 794	.14 173	.15 967	11
50	9.84 046	9.85 815	9.98 231	0.01 769	0.14 185	0.15 954	**10**
51	.84 059	.85 803	.98 256	.01 744	.14 197	.15 941	9
52	.84 072	.85 791	.98 281	.01 719	.14 209	.15 928	8
53	.84 085	.85 779	.98 307	.01 693	.14 221	.15 915	7
54	.84 098	.85 766	.98 332	.01 668	.14 234	.15 902	6
55	9.84 112	9.85 754	9.98 357	0.01 643	0.14 246	0.15 888	**5**
56	.84 125	.85 742	.98 383	.01 617	.14 258	.15 875	4
57	.84 138	.85 730	.98 408	.01 592	.14 270	.15 862	3
58	.84 151	.85 718	.98 433	.01 567	.14 282	.15 849	2
59	.84 164	.85 706	.98 458	.01 542	.14 294	.15 836	1
60	9.84 177	9.85 693	9.98 484	0.01 516	0.14 307	0.15 823	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

133° (313°) (226°) 46°

44° (224°) (315°) **135°**

′	Sin	Cos	Tan	Cot	Sec	Csc	
0	9.84 177	9.85 693	9.98 484	0.01 516	0.14 307	0.15 823	**60**
1	.84 190	.85 681	.98 509	.01 491	.14 319	.15 810	59
2	.84 203	.85 669	.98 534	.01 466	.14 331	.15 797	58
3	.84 216	.85 657	.98 560	.01 440	.14 343	.15 784	57
4	.84 229	.85 645	.98 585	.01 415	.14 355	.15 771	56
5	9.84 242	9.85 632	9.98 610	0.01 390	0.14 368	0.15 758	**55**
6	.84 255	.85 620	.98 635	.01 365	.14 380	.15 745	54
7	.84 269	.85 608	.98 661	.01 339	.14 392	.15 731	53
8	.84 282	.85 596	.98 686	.01 314	.14 404	.15 718	52
9	.84 295	.85 583	.98 711	.01 289	.14 417	.15 705	51
10	9.84 308	9.85 571	9.98 737	0.01 263	0.14 429	0.15 692	**50**
11	.84 321	.85 559	.98 762	.01 238	.14 441	.15 679	49
12	.84 334	.85 547	.98 787	.01 213	.14 453	.15 666	48
13	.84 347	.85 534	.98 812	.01 188	.14 466	.15 653	47
14	.84 360	.85 522	.98 838	.01 162	.14 478	.15 640	46
15	9.84 373	9.85 510	9.98 863	0.01 137	0.14 490	0.15 627	**45**
16	.84 385	.85 497	.98 888	.01 112	.14 503	.15 615	44
17	.84 398	.85 485	.98 913	.01 087	.14 515	.15 602	43
18	.84 411	.85 473	.98 939	.01 061	.14 527	.15 589	42
19	.84 424	.85 460	.98 964	.01 036	.14 540	.15 576	41
20	9.84 437	9.85 448	9.98 989	0.01 011	0.14 552	0.15 563	**40**
21	.84 450	.85 436	.99 015	.00 985	.14 564	.15 550	39
22	.84 463	.85 423	.99 040	.00 960	.14 577	.15 537	38
23	.84 476	.85 411	.99 065	.00 935	.14 589	.15 524	37
24	.84 489	.85 399	.99 090	.00 910	.14 601	.15 511	36
25	9.84 502	9.85 386	9.99 116	0.00 884	0.14 614	0.15 498	**35**
26	.84 515	.85 374	.99 141	.00 859	.14 626	.15 485	34
27	.84 528	.85 361	.99 166	.00 834	.14 639	.15 472	33
28	.84 540	.85 349	.99 191	.00 809	.14 651	.15 460	32
29	.84 553	.85 337	.99 217	.00 783	.14 663	.15 447	31
30	9.84 566	9.85 324	9.99 242	0.00 758	0.14 676	0.15 434	**30**
31	.84 579	.85 312	.99 267	.00 733	.14 688	.15 421	29
32	.84 592	.85 299	.99 293	.00 707	.14 701	.15 408	28
33	.84 605	.85 287	.99 318	.00 682	.14 713	.15 395	27
34	.84 618	.85 274	.99 343	.00 657	.14 726	.15 382	26
35	9.84 630	9.85 262	9.99 368	0.00 632	0.14 738	0.15 370	**25**
36	.84 643	.85 250	.99 394	.00 606	.14 750	.15 357	24
37	.84 656	.85 237	.99 419	.00 581	.14 763	.15 344	23
38	.84 669	.85 225	.99 444	.00 556	.14 775	.15 331	22
39	.84 682	.85 212	.99 469	.00 531	.14 788	.15 318	21
40	9.84 694	9.85 200	9.99 495	0.00 505	0.14 800	0.15 306	**20**
41	.84 707	.85 187	.99 520	.00 480	.14 813	.15 293	19
42	.84 720	.85 175	.99 545	.00 455	.14 825	.15 280	18
43	.84 733	.85 162	.99 570	.00 430	.14 838	.15 267	17
44	.84 745	.85 150	.99 596	.00 404	.14 850	.15 255	16
45	9.84 758	9.85 137	9.99 621	0.00 379	0.14 863	0.15 242	**15**
46	.84 771	.85 125	.99 646	.00 354	.14 875	.15 229	14
47	.84 784	.85 112	.99 672	.00 328	.14 888	.15 216	13
48	.84 796	.85 100	.99 697	.00 303	.14 900	.15 204	12
49	.84 809	.85 087	.99 722	.00 278	.14 913	.15 191	11
50	9.84 822	9.85 074	9.99 747	0.00 253	0.14 926	0.15 178	**10**
51	.84 835	.85 062	.99 773	.00 227	.14 938	.15 165	9
52	.84 847	.85 049	.99 798	.00 202	.14 951	.15 153	8
53	.84 860	.85 037	.99 823	.00 177	.14 963	.15 140	7
54	.84 873	.85 024	.99 848	.00 152	.14 976	.15 127	6
55	9.84 885	9.85 012	9.99 874	0.00 126	0.14 988	0.15 115	**5**
56	.84 898	.84 999	.99 899	.00 101	.15 001	.15 102	4
57	.84 911	.84 986	.99 924	.00 076	.15 014	.15 089	3
58	.84 923	.84 974	.99 949	.00 051	.15 026	.15 077	2
59	.84 936	.84 961	.99 975	.00 025	.15 039	.15 064	1
60	9.84 949	9.84 949	0.00 000	0.00 000	0.15 051	0.15 051	**0**
	Cos	Sin	Cot	Tan	Csc	Sec	′

134° (314°) (225°) **45°**

′	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°	′
0	0.0	59.6	119.2	178.9	238.6	298.3	358.2	418.2	478.3	538.6	**0**
1	1.0	60.6	20.2	79.9	39.6	99.3	59.2	19.2	79.3	39.6	1
2	2.0	61.6	21.2	80.8	40.6	300.3	60.2	20.2	80.3	40.6	2
3	3.0	62.6	22.2	81.8	41.6	01.3	61.2	21.2	81.3	41.6	3
4	4.0	63.6	23.2	82.8	42.5	02.3	62.2	22.2	82.3	42.6	4
5	5.0	64.6	124.2	183.8	243.5	303.3	363.2	423.2	483.3	543.6	**5**
6	6.0	65.6	25.2	84.8	44.5	04.3	64.2	24.2	84.3	44.6	6
7	7.0	66.5	26.2	85.8	45.5	05.3	65.2	25.2	85.3	45.6	7
8	7.9	67.5	27.2	86.8	46.5	06.3	66.2	26.2	86.3	46.6	8
9	8.9	68.5	28.2	87.8	47.5	07.3	67.2	27.2	87.3	47.6	9
10	9.9	69.5	129.1	188.8	248.5	308.3	368.2	428.2	488.3	548.6	**10**
11	10.9	70.5	30.1	89.8	49.5	09.3	69.2	29.2	89.3	49.6	11
12	11.9	71.5	31.1	90.8	50.5	10.3	70.2	30.2	90.4	50.6	12
13	12.9	72.5	32.1	91.8	51.5	11.3	71.2	31.2	91.4	51.7	13
14	13.9	73.5	33.1	92.8	52.5	12.3	72.2	32.2	92.4	52.7	14
15	14.9	74.5	134.1	193.8	253.5	313.3	373.2	433.2	493.4	553.7	**15**
16	15.9	75.5	35.1	94.8	54.5	14.3	74.2	34.2	94.4	54.7	16
17	16.9	76.5	36.1	95.8	55.5	15.3	75.2	35.2	95.4	55.7	17
18	17.9	77.5	37.1	96.8	56.5	16.3	76.2	36.2	96.4	56.7	18
19	18.9	78.5	38.1	97.8	57.5	17.3	77.2	37.2	97.4	57.7	19
20	19.9	79.5	139.1	198.8	258.5	318.3	378.2	438.2	498.4	558.7	**20**
21	20.9	80.5	40.1	99.7	59.5	19.3	79.2	39.2	99.4	59.7	21
22	21.9	81.5	41.1	200.7	60.5	20.3	80.2	40.2	500.4	60.7	22
23	22.8	82.4	42.1	01.7	61.5	21.3	81.2	41.2	01.4	61.7	23
24	23.8	83.4	43.1	02.7	62.5	22.3	82.2	42.2	02.4	62.7	24
25	24.8	84.4	144.1	203.7	263.5	323.3	383.2	443.2	503.4	563.7	**25**
26	25.8	85.4	45.1	04.7	64.5	24.3	84.2	44.2	04.4	64.7	26
27	26.8	86.4	46.0	05.7	65.5	25.3	85.2	45.2	05.4	65.7	27
28	27.8	87.4	47.0	06.7	66.5	26.3	86.2	46.2	06.4	66.8	28
29	28.8	88.4	48.0	07.7	67.4	27.3	87.2	47.2	07.4	67.8	29
30	29.8	89.4	149.0	208.7	268.4	328.3	388.2	448.2	508.4	568.8	**30**
31	30.8	90.4	50.0	09.7	69.4	29.3	89.2	49.2	09.4	69.8	31
32	31.8	91.4	51.0	10.7	70.4	30.3	90.2	50.2	10.4	70.8	32
33	32.8	92.4	52.0	11.7	71.4	31.3	91.2	51.2	11.4	71.8	33
34	33.8	93.4	53.0	12.7	72.4	32.3	92.2	52.2	12.4	72.8	34
35	34.8	94.4	154.0	213.7	273.4	333.3	393.2	453.2	513.4	573.8	**35**
36	35.8	95.4	55.0	14.7	74.4	34.3	94.2	54.3	14.5	74.8	36
37	36.7	96.4	56.0	15.7	75.4	35.3	95.2	55.3	15.5	75.8	37
38	37.7	97.3	57.0	16.7	76.4	36.2	96.2	56.3	16.5	76.8	38
39	38.7	98.3	58.0	17.7	77.4	37.2	97.2	57.3	17.5	77.8	39
40	39.7	99.3	159.0	218.7	278.4	338.2	398.2	458.3	518.5	578.8	**40**
41	40.7	100.3	60.0	19.7	79.4	39.2	99.2	59.3	19.5	79.9	41
42	41.7	01.3	61.0	20.6	80.4	40.2	400.2	60.3	20.5	80.9	42
43	42.7	02.3	62.0	21.6	81.4	41.2	01.2	61.3	21.5	81.9	43
44	43.7	03.3	63.0	22.6	82.4	42.2	02.2	62.3	22.5	82.9	44
45	44.7	104.3	164.0	223.6	283.4	343.2	403.2	463.3	523.5	583.9	**45**
46	45.7	05.3	65.0	24.6	84.4	44.2	04.2	64.3	24.5	84.9	46
47	46.7	06.3	66.0	25.6	85.4	45.2	05.2	65.3	25.5	85.9	47
48	47.7	07.3	67.0	26.6	86.4	46.2	06.2	66.3	26.5	86.9	48
49	48.7	08.3	68.0	27.6	87.4	47.2	07.2	67.3	27.5	87.9	49
50	49.7	109.3	168.9	228.6	288.4	348.2	408.2	468.3	528.5	588.9	**50**
51	50.7	10.3	69.9	29.6	89.4	49.2	09.2	69.3	29.5	89.9	51
52	51.6	11.3	70.9	30.6	90.4	50.2	10.2	70.3	30.5	90.9	52
53	52.6	12.3	71.9	31.6	91.4	51.2	11.2	71.3	31.5	91.9	53
54	53.6	13.2	72.9	32.6	92.4	52.2	12.2	72.3	32.5	93.0	54
55	54.6	114.2	173.9	233.6	293.4	353.2	413.2	473.3	533.5	594.0	**55**
56	55.6	15.2	74.9	34.6	94.4	54.2	14.2	74.3	34.6	95.0	56
57	56.6	16.2	75.9	35.6	95.4	55.2	15.2	75.3	35.6	96.0	57
58	57.6	17.2	76.9	36.6	96.3	56.2	16.2	76.3	36.6	97.0	58
59	58.6	18.2	77.9	37.6	97.3	57.2	17.2	77.3	37.6	98.0	59
60	59.6	119.2	178.9	238.6	298.3	358.2	418.2	478.3	538.6	599.0	**60**
′	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°	′

′	10°	11°	12°	13°	14°	15°	16°	17°	18°	19°	′
0	599.0	659.6	720.5	781.5	842.8	904.4	966.3	1028.5	1091.0	1153.9	**0**
1	600.0	60.6	21.5	82.5	43.9	05.4	67.3	29.5	92.0	54.9	1
2	01.0	61.7	22.5	83.6	44.9	06.5	68.3	30.5	93.1	56.0	2
3	02.0	62.7	23.5	84.6	45.9	07.5	69.4	31.6	94.1	57.0	3
4	03.0	63.7	24.5	85.6	46.9	08.5	70.4	32.6	95.2	58.1	4
5	604.1	664.7	725.5	786.6	847.9	909.6	971.4	1033.7	1096.2	1159.1	**5**
6	05.1	65.7	26.6	87.6	49.0	10.6	72.5	34.7	97.3	60.2	6
7	06.1	66.7	27.6	88.7	50.0	11.6	73.5	35.7	98.3	61.2	7
8	07.1	67.7	28.6	89.7	51.0	12.6	74.6	36.8	99.4	62.3	8
9	08.1	68.7	29.6	90.7	52.0	13.7	75.6	37.8	1100.4	63.3	9
10	609.1	669.8	730.6	791.7	853.1	914.7	976.6	1038.9	1101.4	1164.4	**10**
11	10.1	70.8	31.6	92.7	54.1	15.7	77.7	39.9	02.5	65.4	11
12	11.1	71.8	32.7	93.8	55.1	16.8	78.7	40.9	03.5	66.5	12
13	12.1	72.8	33.7	94.8	56.1	17.8	79.7	42.0	04.6	67.5	13
14	13.1	73.8	34.7	95.8	57.2	18.8	80.8	43.0	05.6	68.6	14
15	614.1	674.8	735.7	796.8	858.2	919.8	981.8	1044.1	1106.7	1169.7	**15**
16	15.2	75.8	36.7	97.8	59.2	20.9	82.8	45.1	07.7	70.7	16
17	16.2	76.8	37.7	98.9	60.2	21.9	83.9	46.1	08.8	71.8	17
18	17.2	77.9	38.8	99.9	61.3	22.9	84.9	47.2	09.8	72.8	18
19	18.2	78.9	39.8	800.9	62.3	24.0	85.9	48.2	10.9	73.9	19
20	619.2	679.9	740.8	801.9	863.3	925.0	987.0	1049.3	1111.9	1174.9	**20**
21	20.2	80.9	41.8	02.9	64.3	26.0	88.0	50.3	13.0	76.0	21
22	21.2	81.9	42.8	04.0	65.4	27.1	89.0	51.3	14.0	77.0	22
23	22.2	82.9	43.8	05.0	66.4	28.1	90.1	52.4	15.0	78.1	23
24	23.2	83.9	44.9	06.0	67.4	29.1	91.1	53.4	16.1	79.1	24
25	624.2	684.9	745.9	807.0	868.5	930.1	992.1	1054.5	1117.1	1180.2	**25**
26	25.3	86.0	46.9	08.1	69.5	31.2	93.2	55.5	18.2	81.2	26
27	26.3	87.0	47.9	09.1	70.5	32.2	94.2	56.6	19.2	82.3	27
28	27.3	88.0	48.9	10.1	71.5	33.2	95.3	57.6	20.3	83.3	28
29	28.3	89.0	49.9	11.1	72.6	34.3	96.3	58.6	21.3	84.4	29
30	629.3	690.0	751.0	812.1	873.6	935.3	997.3	1059.7	1122.4	1185.5	**30**
31	30.3	91.0	52.0	13.2	74.6	36.3	98.4	60.7	23.4	86.5	31
32	31.3	92.0	53.0	14.2	75.6	37.4	99.4	61.8	24.5	87.6	32
33	32.3	93.1	54.0	15.2	76.7	38.4	1000.4	62.8	25.5	88.6	33
34	33.3	94.1	55.0	16.2	77.7	39.4	01.5	63.9	26.6	89.7	34
35	634.3	695.1	756.0	817.3	878.7	940.5	1002.5	1064.9	1127.6	1190.7	**35**
36	35.4	96.1	57.1	18.3	79.7	41.5	03.6	65.9	28.7	91.8	36
37	36.4	97.1	58.1	19.3	80.8	42.5	04.6	67.0	29.7	92.8	37
38	37.4	98.1	59.1	20.3	81.8	43.6	05.6	68.0	30.8	93.9	38
39	38.4	99.1	60.1	21.3	82.8	44.6	06.7	69.1	31.8	95.0	39
40	639.4	700.2	761.1	822.4	883.8	945.6	1007.7	1070.1	1132.9	1196.0	**40**
41	40.4	01.2	62.2	23.4	84.9	46.7	08.7	71.2	33.9	97.1	41
42	41.4	02.2	63.2	24.4	85.9	47.7	09.8	72.2	35.0	98.1	42
43	42.4	03.2	64.2	25.4	86.9	48.7	10.8	73.2	36.0	99.2	43
44	43.4	04.2	65.2	26.5	88.0	49.7	11.8	74.3	37.1	1200.2	44
45	644.5	705.2	766.2	827.5	889.0	950.8	1012.9	1075.3	1138.1	1201.3	**45**
46	45.5	06.2	67.3	28.5	90.0	51.8	13.9	76.4	39.2	02.3	46
47	46.5	07.3	68.3	29.5	91.0	52.8	15.0	77.4	40.2	03.4	47
48	47.5	08.3	69.3	30.5	92.1	53.9	16.0	78.5	41.3	04.5	48
49	48.5	09.3	70.3	31.6	93.1	54.9	17.0	79.5	42.3	05.5	49
50	649.5	710.3	771.3	832.6	894.1	955.9	1018.1	1080.5	1143.4	1206.6	**50**
51	50.5	11.3	72.3	33.6	95.2	57.0	19.1	81.6	44.4	07.6	51
52	51.5	12.3	73.4	34.6	96.2	58.0	20.2	82.6	45.5	08.7	52
53	52.5	13.4	74.4	35.7	97.2	59.0	21.2	83.7	46.5	09.7	53
54	53.6	14.4	75.4	36.7	98.2	60.1	22.2	84.7	47.6	10.8	54
55	654.6	715.4	776.4	837.7	899.3	961.1	1023.3	1085.8	1148.6	1211.8	**55**
56	55.6	16.4	77.4	38.7	900.3	62.1	24.3	86.8	49.7	12.9	56
57	56.6	17.4	78.5	39.8	01.3	63.2	25.3	87.9	50.7	14.0	57
58	57.6	18.4	79.5	40.8	02.3	64.2	26.4	88.9	51.8	15.0	58
59	58.6	19.4	80.5	41.8	03.4	65.2	27.4	89.9	52.8	16.1	59
60	659.6	720.5	781.5	842.8	904.4	966.3	1028.5	1091.0	1153.9	1217.1	**60**
′	10°	11°	12°	13°	14°	15°	16°	17°	18°	19°	′

′	20°	21°	22°	23°	24°	25°	26°	27°	28°	29°	′
0	1217.1	1280.8	1344.9	1409.5	1474.5	1540.1	1606.2	1672.9	1740.2	1808.1	**0**
1	18.2	81.9	46.0	10.6	75.6	41.2	07.3	74.0	41.3	09.2	1
2	19.3	82.9	47.1	11.6	76.7	42.3	08.4	75.1	42.4	10.4	2
3	20.3	84.0	48.1	12.7	77.8	43.4	09.5	76.2	43.6	11.5	3
4	21.4	85.1	49.2	13.8	78.9	44.5	10.6	77.4	44.7	12.6	4
5	1222.4	1286.1	1350.3	1414.9	1480.0	1545.6	1611.7	1678.5	1745.8	1813.8	**5**
6	23.5	87.2	51.4	16.0	81.1	46.7	12.9	79.6	46.9	14.9	6
7	24.5	88.3	52.4	17.1	82.2	47.8	14.0	80.7	48.1	16.1	7
8	25.6	89.3	53.5	18.1	83.3	48.9	15.1	81.8	49.2	17.2	8
9	26.7	90.4	54.6	19.2	84.3	50.0	16.2	82.9	50.3	18.3	9
10	1227.7	1291.5	1355.7	1420.3	1485.4	1551.1	1617.3	1684.1	1751.5	1819.5	**10**
11	28.8	92.5	56.7	21.4	86.5	52.2	18.4	85.2	52.6	20.6	11
12	29.8	93.6	57.8	22.5	87.6	53.3	19.5	86.3	53.7	21.8	12
13	30.9	94.7	58.9	23.5	88.7	54.4	20.6	87.4	54.8	22.9	13
14	32.0	95.7	59.9	24.6	89.8	55.5	21.7	88.5	56.0	24.0	14
15	1233.0	1296.8	1361.0	1425.7	1490.9	1556.6	1622.8	1689.7	1757.1	1825.2	**15**
16	34.1	97.9	62.1	26.8	92.0	57.7	23.9	90.8	58.2	26.3	16
17	35.1	98.9	63.2	27.9	93.1	58.8	25.0	91.9	59.4	27.5	17
18	36.2	1300.0	64.2	29.0	94.2	59.9	26.2	93.0	60.5	28.6	18
19	37.3	01.1	65.3	30.0	95.2	61.0	27.3	94.1	61.6	29.7	19
20	1238.3	1302.1	1366.4	1431.1	1496.3	1562.1	1628.4	1695.3	1762.7	1830.9	**20**
21	39.4	03.2	67.5	32.2	97.4	63.2	29.5	96.4	63.9	32.0	21
22	40.4	04.3	68.5	33.3	98.5	64.3	30.6	97.5	65.0	33.2	22
23	41.5	05.3	69.6	34.4	99.6	65.4	31.7	98.6	66.1	34.3	23
24	42.6	06.4	70.7	35.4	1500.7	66.5	32.8	99.7	67.3	35.4	24
25	1243.6	1307.5	1371.8	1436.5	1501.8	1567.6	1633.9	1700.9	1768.4	1836.6	**25**
26	44.7	08.5	72.8	37.6	02.9	68.7	35.0	02.0	69.5	37.7	26
27	45.7	09.6	73.9	38.7	04.0	69.8	36.1	03.1	70.7	38.9	27
28	46.8	10.7	75.0	39.8	05.1	70.9	37.3	04.2	71.8	40.0	28
29	47.9	11.7	76.1	40.9	06.2	72.0	38.4	05.3	72.9	41.2	29
30	1248.9	1312.8	1377.1	1442.0	1507.3	1573.1	1639.5	1706.5	1774.1	1842.3	**30**
31	50.0	13.9	78.2	43.0	08.4	74.2	40.6	07.6	75.2	43.4	31
32	51.0	14.9	79.3	44.1	09.4	75.3	41.7	08.7	76.3	44.6	32
33	52.1	16.0	80.4	45.2	10.5	76.4	42.8	09.8	77.4	45.7	33
34	53.2	17.1	81.5	46.3	11.6	77.5	43.9	10.9	78.6	46.9	34
35	1254.2	1318.2	1382.5	1447.4	1512.7	1578.6	1645.0	1712.1	1779.7	1848.0	**35**
36	55.3	19.2	83.6	48.5	13.8	79.7	46.2	13.2	80.8	49.2	36
37	56.4	20.3	84.7	49.5	14.9	80.8	47.3	14.3	82.0	50.3	37
38	57.4	21.4	85.8	50.6	16.0	81.9	48.4	15.4	83.1	51.4	38
39	58.5	22.4	86.8	51.7	17.1	83.0	49.5	16.6	84.2	52.6	39
40	1259.5	1323.5	1387.9	1452.8	1518.2	1584.1	1650.6	1717.7	1785.4	1853.7	**40**
41	60.6	24.6	89.0	53.9	19.3	85.2	51.7	18.8	86.5	54.9	41
42	61.7	25.6	90.1	55.0	20.4	86.3	52.8	19.9	87.6	56.0	42
43	62.7	26.7	91.1	56.1	21.5	87.4	53.9	21.1	88.8	57.2	43
44	63.8	27.8	92.2	57.1	22.6	88.5	55.1	22.2	89.9	58.3	44
45	1264.9	1328.9	1393.3	1458.2	1523.7	1589.6	1656.2	1723.3	1791.1	1859.5	**45**
46	65.9	29.9	94.4	59.3	24.8	90.7	57.3	24.4	92.2	60.6	46
47	67.0	31.0	95.5	60.4	25.9	91.8	58.4	25.5	93.3	61.8	47
48	68.0	32.1	96.5	61.5	27.0	92.9	59.5	26.7	94.5	62.9	48
49	69.1	33.1	97.6	62.6	28.0	94.1	60.6	27.8	95.6	64.0	49
50	1270.2	1334.2	1398.7	1463.7	1529.1	1595.2	1661.7	1728.9	1796.7	1865.2	**50**
51	71.2	35.3	99.8	64.8	30.2	96.3	62.9	30.0	97.9	66.3	51
52	72.3	36.3	1400.9	65.8	31.3	97.4	64.0	31.2	99.0	67.5	52
53	73.4	37.4	01.9	66.9	32.4	98.5	65.1	32.3	1800.1	68.6	53
54	74.4	38.5	03.0	68.0	33.5	99.6	66.2	33.4	01.3	69.8	54
55	1275.5	1339.6	1404.1	1469.1	1534.6	1600.7	1667.3	1734.5	1802.4	1870.9	**55**
56	76.6	40.6	05.2	70.2	35.7	01.8	68.4	35.7	03.5	72.1	56
57	77.6	41.7	06.2	71.3	36.8	02.9	69.5	36.8	04.7	73.2	57
58	78.7	42.8	07.3	72.4	37.9	04.0	70.7	37.9	05.8	74.4	58
59	79.7	43.8	08.4	73.5	39.0	05.1	71.8	39.1	07.0	75.5	59
60	1280.8	1344.9	1409.5	1474.5	1540.1	1606.2	1672.9	1740.2	1808.1	1876.7	**60**
′	20°	21°	22°	23°	24°	25°	26°	27°	28°	29°	′

′	30°	31°	32°	33°	34°	35°	36°	37°	38°	39°	′
0	1876.7	1946.0	2016.0	2086.8	2158.4	2230.9	2304.2	2378.5	2453.8	2530.2	**0**
1	77.8	47.1	17.2	88.0	59.6	32.1	05.5	79.8	55.1	31.5	1
2	79.0	48.3	18.3	89.2	60.8	33.3	06.7	81.0	56.4	32.8	2
3	80.1	49.4	19.5	90.3	62.0	34.5	07.9	82.3	57.6	34.0	3
4	81.3	50.6	20.7	91.5	63.2	35.7	09.2	83.5	58.9	35.3	4
5	1882.4	1951.8	2021.9	2092.7	2164.4	2236.9	2310.4	2384.8	2460.2	2536.6	**5**
6	83.6	52.9	23.0	93.9	65.6	38.2	11.6	86.0	61.4	37.9	6
7	84.7	54.1	24.2	95.1	66.8	39.4	12.9	87.3	62.7	39.2	7
8	85.9	55.3	25.4	96.3	68.0	40.6	14.1	88.5	64.0	40.5	8
9	87.0	56.4	26.6	97.5	69.2	41.8	15.3	89.8	65.2	41.7	9
10	1888.2	1957.6	2027.7	2098.7	2170.4	2243.0	2316.5	2391.0	2466.5	2543.0	**10**
11	89.3	58.7	28.9	99.8	71.6	44.2	17.8	92.3	67.8	44.3	11
12	90.5	59.9	30.1	2101.0	72.8	45.5	19.0	93.5	69.0	45.6	12
13	91.6	61.1	31.3	02.2	74.0	46.7	20.3	94.8	70.3	46.9	13
14	92.8	62.2	32.4	03.4	75.2	47.9	21.5	96.0	71.6	48.2	14
15	1893.9	1963.4	2033.6	2104.6	2176.4	2249.1	2322.7	2397.3	2472.8	2549.5	**15**
16	95.1	64.6	34.8	05.8	77.6	50.3	24.0	98.5	74.1	50.7	16
17	96.2	65.7	36.0	07.0	78.8	51.6	25.2	99.8	75.4	52.0	17
18	97.4	66.9	37.1	08.2	80.0	52.8	26.4	2401.0	76.6	53.3	18
19	98.5	68.1	38.3	09.4	81.2	54.0	27.7	02.3	77.9	54.6	19
20	1899.7	1969.2	2039.5	2110.6	2182.5	2255.2	2328.9	2403.5	2479.2	2555.9	**20**
21	1900.8	70.4	40.7	11.8	83.7	56.4	30.1	04.8	80.4	57.2	21
22	02.0	71.5	41.8	12.9	84.9	57.7	31.4	06.0	81.7	58.5	22
23	03.1	72.7	43.0	14.1	86.1	58.9	32.6	07.3	83.0	59.8	23
24	04.3	73.9	44.2	15.3	87.3	60.1	33.8	08.5	84.3	61.0	24
25	1905.5	1975.0	2045.4	2116.5	2188.5	2261.3	2335.1	2409.8	2485.5	2562.3	**25**
26	06.6	76.2	46.6	17.7	89.7	62.5	36.3	11.1	86.8	63.6	26
27	07.8	77.4	47.7	18.9	90.9	63.8	37.6	12.3	88.1	64.9	27
28	08.9	78.5	48.9	20.1	92.1	65.0	38.8	13.6	89.3	66.2	28
29	10.1	79.7	50.1	21.3	93.3	66.2	40.0	14.8	90.6	67.5	29
30	1911.2	1980.9	2051.3	2122.5	2194.5	2267.4	2341.3	2416.1	2491.9	2568.8	**30**
31	12.4	82.0	52.5	23.7	95.7	68.7	42.5	17.3	93.2	70.1	31
32	13.5	83.2	53.6	24.9	96.9	69.9	43.7	18.6	94.4	71.4	32
33	14.7	84.4	54.8	26.1	98.1	71.1	45.0	19.8	95.7	72.7	33
34	15.8	85.5	56.0	27.3	99.4	72.3	46.2	21.1	97.0	73.9	34
35	1917.0	1986.7	2057.2	2128.5	2200.6	2273.5	2347.5	2422.3	2498.3	2575.2	**35**
36	18.2	87.9	58.4	29.6	01.8	74.8	48.7	23.6	99.5	76.5	36
37	19.3	89.1	59.5	30.8	03.0	76.0	49.9	24.9	2500.8	77.8	37
38	20.5	90.2	60.7	32.0	04.2	77.2	51.2	26.1	02.1	79.1	38
39	21.6	91.4	61.9	33.2	05.4	78.4	52.4	27.4	03.4	80.4	39
40	1922.8	1992.6	2063.1	2134.4	2206.6	2279.7	2353.7	2428.6	2504.6	2581.7	**40**
41	23.9	93.7	64.3	35.6	07.8	80.9	54.9	29.9	05.9	83.0	41
42	25.1	94.9	65.5	36.8	09.0	82.1	56.1	31.2	07.2	84.3	42
43	26.3	96.1	66.6	38.0	10.2	83.3	57.4	32.4	08.5	85.6	43
44	27.4	97.2	67.8	39.2	11.5	84.6	58.6	33.7	09.7	86.9	44
45	1928.6	1998.4	2069.0	2140.4	2212.7	2285.8	2359.9	2434.9	2511.0	2588.2	**45**
46	29.7	99.6	70.2	41.6	13.9	87.0	61.1	36.2	12.3	89.5	46
47	30.9	2000.7	71.4	42.8	15.1	88.3	62.4	37.4	13.6	90.8	47
48	32.0	01.9	72.6	44.0	16.3	89.5	63.6	38.7	14.8	92.1	48
49	33.2	03.1	73.7	45.2	17.5	90.7	64.8	40.0	16.1	93.4	49
50	1934.4	2004.3	2074.9	2146.4	2218.7	2291.9	2366.1	2441.2	2517.4	2594.7	**50**
51	35.5	05.4	76.1	47.6	19.9	93.2	67.3	42.5	18.7	96.0	51
52	36.7	06.6	77.3	48.8	21.1	94.4	68.6	43.7	20.0	97.3	52
53	37.8	07.8	78.5	50.0	22.4	95.6	69.8	45.0	21.2	98.5	53
54	39.0	08.9	79.7	51.2	23.6	96.9	71.1	46.3	22.5	99.8	54
55	1940.2	2010.1	2080.8	2152.4	2224.8	2298.1	2372.3	2447.5	2523.8	2601.1	**55**
56	41.3	11.3	82.0	53.6	26.0	99.3	73.6	48.8	25.1	02.4	56
57	42.5	12.5	83.2	54.8	27.2	2300.5	74.8	50.1	26.4	03.7	57
58	43.6	13.6	84.4	56.0	28.4	01.8	76.1	51.3	27.6	05.0	58
59	44.8	14.8	85.6	57.2	29.6	03.0	77.3	52.6	28.9	06.3	59
60	1946.0	2016.0	2086.8	2158.4	2230.9	2304.2	2378.5	2453.8	2530.2	2607.6	**60**
′	30°	31°	32°	33°	34°	35°	36°	37°	38°	39°	′

′	40°	41°	42°	43°	44°	45°	46°	47°	48°	49°	′
0	2607.6	2686.2	2766.0	2847.1	2929.5	3013.4	3098.7	3185.6	3274.1	3364.4	**0**
1	08.9	87.6	67.4	48.5	30.9	14.8	3100.1	87.1	75.6	65.9	1
2	10.2	88.9	68.7	49.9	32.3	16.2	01.6	88.5	77.1	67.4	2
3	11.5	90.2	70.1	51.2	33.7	17.6	03.0	90.0	78.6	69.0	3
4	12.8	91.5	71.4	52.6	35.1	19.0	04.4	91.4	80.1	70.5	4
5	2614.1	2692.8	2772.8	2853.9	2936.5	3020.4	3105.9	3192.9	3281.6	3372.0	**5**
6	15.4	94.2	74.1	55.3	37.9	21.8	07.3	94.4	83.1	73.5	6
7	16.8	95.5	75.4	56.7	39.3	23.3	08.8	95.8	84.6	75.1	7
8	18.1	96.8	76.8	58.0	40.6	24.7	10.2	97.3	86.1	76.6	8
9	19.4	98.1	78.1	59.4	42.0	26.1	11.6	98.8	87.6	78.1	9
10	2620.7	2699.5	2779.5	2860.8	2943.4	3027.5	3113.1	3200.2	3289.0	3379.6	**10**
11	22.0	2700.8	80.8	62.1	44.8	28.9	14.5	01.7	90.5	81.2	11
12	23.3	02.1	82.2	63.5	46.2	30.3	16.0	03.2	92.0	82.7	12
13	24.6	03.4	83.5	64.9	47.6	31.7	17.4	04.6	93.5	84.2	13
14	25.9	04.8	84.8	66.2	49.0	33.2	18.8	06.1	95.0	85.7	14
15	2627.2	2706.1	2786.2	2867.6	2950.4	3034.6	3120.3	3207.6	3296.5	3387.3	**15**
16	28.5	07.4	87.5	69.0	51.8	36.0	21.7	09.0	98.0	88.8	16
17	29.8	08.7	88.9	70.3	53.2	37.4	23.2	10.5	99.5	90.3	17
18	31.1	10.1	90.2	71.7	54.5	38.8	24.6	12.0	3301.0	91.8	18
19	32.4	11.4	91.6	73.1	55.9	40.2	26.0	13.4	02.5	93.4	19
20	2633.7	2712.7	2792.9	2874.4	2957.3	3041.7	3127.5	3214.9	3304.0	3394.9	**20**
21	35.0	14.0	94.3	75.8	58.7	43.1	28.9	16.4	05.5	96.4	21
22	36.3	15.4	95.6	77.2	60.1	44.5	30.4	17.9	07.0	98.0	22
23	37.6	16.7	97.0	78.6	61.5	45.9	31.8	19.3	08.5	99.5	23
24	38.9	18.0	98.3	79.9	62.9	47.3	33.3	20.8	10.0	3401.0	24
25	2640.2	2719.3	2799.7	2881.3	2964.3	3048.7	3134.7	3222.3	3311.5	3402.6	**25**
26	41.6	20.7	2801.0	82.7	65.7	50.2	36.2	23.7	13.0	04.1	26
27	42.9	22.0	02.4	84.0	67.1	51.6	37.6	25.2	14.5	05.6	27
28	44.2	23.3	03.7	85.4	68.5	53.0	39.0	26.7	16.0	07.2	28
29	45.5	24.7	05.1	86.8	69.9	54.4	40.5	28.2	17.5	08.7	29
30	2646.8	2726.0	2806.4	2888.2	2971.3	3055.9	3141.9	3229.6	3319.0	3410.2	**30**
31	48.1	27.3	07.8	89.5	72.7	57.3	43.4	31.1	20.5	11.8	31
32	49.4	28.6	09.1	90.9	74.1	58.7	44.8	32.6	22.1	13.3	32
33	50.7	30.0	10.5	92.3	75.5	60.1	46.3	34.1	23.6	14.8	33
34	52.0	31.3	11.8	93.7	76.9	61.5	47.7	35.6	25.1	16.4	34
35	2653.3	2732.6	2813.2	2895.0	2978.3	3063.0	3149.2	3237.0	3326.6	3417.9	**35**
36	54.7	34.0	14.5	96.4	79.7	64.4	50.6	38.5	28.1	19.5	36
37	56.0	35.3	15.9	97.8	81.1	65.8	52.1	40.0	29.6	21.0	37
38	57.3	36.6	17.2	99.2	82.5	67.2	53.5	41.5	31.1	22.5	38
39	58.6	38.0	18.6	2900.5	83.9	68.7	55.0	42.9	32.6	24.1	39
40	2659.9	2739.3	2820.0	2901.9	2985.3	3070.1	3156.4	3244.4	3334.1	3425.6	**40**
41	61.2	40.6	21.3	03.3	86.7	71.5	57.9	45.9	35.6	27.2	41
42	62.5	42.0	22.7	04.7	88.1	72.9	59.4	47.4	37.1	28.7	42
43	63.9	43.3	24.0	06.1	89.5	74.4	60.8	48.9	38.6	30.2	43
44	65.2	44.6	25.4	07.4	90.9	75.8	62.3	50.3	40.2	31.8	44
45	2666.5	2746.0	2826.7	2908.8	2992.3	3077.2	3163.7	3251.8	3341.7	3433.3	**45**
46	67.8	47.3	28.1	10.2	93.7	78.7	65.2	53.3	43.2	34.9	46
47	69.1	48.6	29.4	11.6	95.1	80.1	66.6	54.8	44.7	36.4	47
48	70.4	50.0	30.8	13.0	96.5	81.5	68.1	56.3	46.2	38.0	48
49	71.7	51.3	32.2	14.3	97.9	82.9	69.5	57.8	47.7	39.5	49
50	2673.1	2752.7	2833.5	2915.7	2999.3	3084.4	3171.0	3259.3	3349.2	3441.0	**50**
51	74.4	54.0	34.9	17.1	3000.7	85.8	72.5	60.7	50.8	42.6	51
52	75.7	55.3	36.2	18.5	02.1	87.2	73.9	62.2	52.3	44.1	52
53	77.0	56.7	37.6	19.9	03.5	88.7	75.4	63.7	53.8	45.7	53
54	78.3	58.0	39.0	21.2	04.9	90.1	76.8	65.2	55.3	47.2	54
55	2679.6	2759.3	2840.3	2922.6	3006.3	3091.5	3178.3	3266.7	3356.8	3448.8	**55**
56	81.0	60.7	41.7	24.0	07.7	93.0	79.7	68.2	58.3	50.3	56
57	82.3	62.0	43.0	25.4	09.2	94.4	81.2	69.7	59.9	51.9	57
58	83.6	63.4	44.4	26.8	10.6	95.8	82.7	71.1	61.4	53.4	58
59	84.9	64.7	45.8	28.2	12.0	97.3	84.1	72.6	62.9	55.0	59
60	2686.2	2766.0	2847.1	2929.5	3013.4	3098.7	3185.6	3274.1	3364.4	3456.5	**60**
′	40°	41°	42°	43°	44°	45°	46°	47°	48°	49°	′

′	50°	51°	52°	53°	54°	55°	56°	57°	58°	59°	′
0	3456.5	3550.6	3646.7	3745.1	3845.7	3948.8	4054.5	4163.0	4274.4	4389.1	**0**
1	58.1	52.2	48.4	46.7	47.4	50.5	56.3	64.8	76.3	91.0	1
2	59.6	53.8	50.0	48.4	49.1	52.3	58.1	66.6	78.2	92.9	2
3	61.2	55.4	51.6	50.0	50.8	54.0	59.8	68.5	80.1	94.9	3
4	62.7	56.9	53.2	51.7	52.5	55.7	61.6	70.3	82.0	96.8	4
5	3464.3	3558.5	3654.8	3753.4	3854.2	3957.5	4063.4	4172.1	4283.9	4398.8	**5**
6	65.9	60.1	56.5	55.0	55.9	59.2	65.2	74.0	85.7	4400.7	6
7	67.4	61.7	58.1	56.7	57.6	61.0	67.0	75.8	87.6	02.6	7
8	69.0	63.3	59.7	58.3	59.3	62.7	68.8	77.7	89.5	04.6	8
9	70.5	64.9	61.3	60.0	61.0	64.5	70.6	79.5	91.4	06.5	9
10	3472.1	3566.5	3663.0	3761.7	3862.7	3966.2	4072.4	4181.3	4293.3	4408.5	**10**
11	73.6	68.1	64.6	63.3	64.4	68.0	74.2	83.2	95.2	10.4	11
12	75.2	69.7	66.2	65.0	66.1	69.7	76.0	85.0	97.1	12.4	12
13	76.7	71.3	67.9	66.7	67.8	71.5	77.7	86.9	99.0	14.3	13
14	78.3	72.8	69.5	68.3	69.5	73.2	79.5	88.7	4300.9	16.3	14
15	3479.9	3574.4	3671.1	3770.0	3871.2	3975.0	4081.3	4190.6	4302.8	4418.2	**15**
16	81.4	76.0	72.7	71.7	72.9	76.7	83.1	92.4	04.7	20.2	16
17	83.0	77.6	74.4	73.3	74.6	78.5	84.9	94.2	06.6	22.1	17
18	84.5	79.2	76.0	75.0	76.3	80.2	86.7	96.1	08.5	24.1	18
19	86.1	80.8	77.6	76.7	78.1	82.0	88.5	97.9	10.4	26.1	19
20	3487.7	3582.4	3679.3	3778.3	3879.8	3983.7	4090.3	4199.8	4312.3	4428.0	**20**
21	89.2	84.0	80.9	80.0	81.5	85.5	92.1	4201.6	14.2	30.0	21
22	90.8	85.6	82.5	81.7	83.2	87.2	93.9	03.5	16.1	31.9	22
23	92.4	87.2	84.2	83.3	84.9	89.0	95.7	05.3	18.0	33.9	23
24	93.9	88.8	85.8	85.0	86.6	90.7	97.5	07.2	19.9	35.8	24
25	3495.5	3590.4	3687.4	3786.7	3888.3	3992.5	4099.3	4209.0	4321.8	4437.8	**25**
26	97.1	92.0	89.1	88.4	90.0	94.3	4101.1	10.9	23.7	39.8	26
27	98.6	93.6	90.7	90.0	91.8	96.0	02.9	12.8	25.6	41.7	27
28	3500.2	95.2	92.3	91.7	93.5	97.8	04.8	14.6	27.5	43.7	28
29	01.8	96.8	94.0	93.4	95.2	99.5	06.6	16.5	29.4	45.7	29
30	3503.3	3598.4	3695.6	3795.1	3896.9	4001.3	4108.4	4218.3	4331.3	4447.6	**30**
31	04.9	3600.0	97.3	96.8	98.6	03.1	10.2	20.2	33.2	49.6	31
32	06.5	01.6	98.9	98.4	3900.4	04.8	12.0	22.0	35.2	51.6	32
33	08.0	03.2	3700.5	3800.1	02.1	06.6	13.8	23.9	37.1	53.5	33
34	09.6	04.8	02.2	01.8	03.8	08.3	15.6	25.8	39.0	55.5	34
35	3511.2	3606.4	3703.8	3803.5	3905.5	4010.1	4117.4	4227.6	4340.9	4457.5	**35**
36	12.7	08.0	05.5	05.1	07.2	11.9	19.2	29.5	42.8	59.4	36
37	14.3	09.6	07.1	06.8	09.0	13.6	21.0	31.3	44.7	61.4	37
38	15.9	11.2	08.7	08.5	10.7	15.4	22.9	33.2	46.6	63.4	38
39	17.5	12.8	10.4	10.2	12.4	17.2	24.7	35.1	48.6	65.4	39
40	3519.0	3614.5	3712.0	3811.9	3914.1	4018.9	4126.5	4236.9	4350.5	4467.3	**40**
41	20.6	16.1	13.7	13.6	15.9	20.7	28.3	38.8	52.4	69.3	41
42	22.2	17.7	15.3	15.2	17.6	22.5	30.1	40.7	54.3	71.3	42
43	23.7	19.3	17.0	17.0	19.3	24.3	31.9	42.5	56.2	73.3	43
44	25.3	20.9	18.6	18.6	21.0	26.0	33.8	44.4	58.2	75.3	44
45	3526.9	3622.5	3720.3	3820.3	3922.8	4027.8	4135.6	4246.3	4360.1	4477.2	**45**
46	28.5	24.1	21.9	22.0	24.5	29.6	37.4	48.1	62.0	79.2	46
47	30.1	25.7	23.6	23.7	26.2	31.4	39.2	50.0	63.9	81.2	47
48	31.6	27.3	25.2	25.4	28.0	33.1	41.0	51.9	65.9	83.2	48
49	33.2	29.0	26.9	27.1	29.7	34.9	42.9	53.8	67.8	85.2	49
50	3534.8	3630.6	3728.5	3828.7	3931.4	4036.7	4144.7	4255.6	4369.7	4487.2	**50**
51	36.4	32.2	30.2	30.4	33.2	38.5	46.5	57.5	71.7	89.1	51
52	37.9	33.8	31.8	32.1	34.9	40.2	48.3	59.4	73.6	91.1	52
53	39.5	35.4	33.5	33.8	36.6	42.0	50.2	61.3	75.5	93.1	53
54	41.1	37.0	35.1	35.5	38.4	43.8	52.0	63.1	77.4	95.1	54
55	3542.7	3638.6	3736.8	3837.2	3940.1	4045.6	4153.8	4265.0	4379.4	4497.1	**55**
56	44.3	40.3	38.4	38.9	41.8	47.4	55.7	66.9	81.3	99.1	56
57	45.9	41.9	40.1	40.6	43.6	49.1	57.5	68.8	83.2	4501.1	57
58	47.4	43.5	41.7	42.3	45.3	50.9	59.3	70.7	85.2	03.1	58
59	49.0	45.1	43.4	45.0	47.0	52.7	61.1	72.5	87.1	05.1	59
60	3550.6	3646.7	3745.1	3845.7	3948.8	4054.5	4163.0	4274.4	4389.1	4507.1	**60**
′	50°	51°	52°	53°	54°	55°	56°	57°	58°	59°	′

Combined Correction for Observed Sextant Altitudes

Observed Altitude	Correction: For **Sun** (to be **added** to observed altitude)	Correction: For **Star** (to be **subtracted** from observed altitude)
5°	6′ 14″	9′ 55″
6	7 41	8 28
7	8 45	7 24
8	9 35	6 34
9	10 16	5 53
10	10 50	5 19
11	11 17	4 51
12	11 41	4 27
13	12 2	4 7
14	12 19	3 49
15	12 34	3 34
20	13 29	2 39
25	14 3	2 5
30	14 26	1 41
35	14 44	1 23
40	14 57	1 10
45	15 8	0 58
50	15 17	0 49
55	15 25	0 40
60	15 31	0 34
65	15 37	0 27
70	15 42	0 21
75	15 47	0 16
80	15 52	0 10
85	15 55	0 5

Small supplementary correction, for Sun only.

Jan. to March and Oct. to Dec. } add 10″.
April to Sept., subtract 10″.

Correction for Dip of Sea Horizon (Sun or Star)

Height of Observer's Eye Above Sea Level (feet)	Dip Correction (to be **subtracted** from observed altitude)
4	1′ 58″
6	2 24
8	2 46
10	3 06
12	3 24
14	3 40
16	3 55
18	4 9
20	4 23
22	4 36
24	4 48
26	5 0
28	5 11
30	5 22
35	5 48
40	6 12
45	6 36
50	6 56
55	7 16
60	7 35
70	8 12
85	9 2
100	9 48

The dip correction is not required when the artificial horizon is used.

To Change Hours and Minutes into Decimals of a Day

HOURS EXPRESSED AS DECIMAL PARTS OF A DAY

Hours	Decimal
1	.0416
2	.0833
3	.1250
4	.1666
5	.2083
6	.2500
7	.2916
8	.3333
9	.3750
10	.4166
11	.4583
12	.5000
13	.5416
14	.5833
15	.6249
16	.6666
17	.7083
18	.7500
19	.7916
20	.8333
21	.8749
22	.9166
23	.9583
24	1.0000

MINUTES EXPRESSED AS DECIMAL PARTS OF A DAY

Minutes	Decimal	Minutes	Decimal
1	.0006	31	.0215
2	.0013	32	.0222
3	.0020	33	.0229
4	.0027	34	.0236
5	.0034	35	.0243
6	.0041	36	.0250
7	.0048	37	.0256
8	.0055	38	.0263
9	.0062	39	.0270
10	.0069	40	.0277
11	.0076	41	.0284
12	.0083	42	.0291
13	.0090	43	.0298
14	.0097	44	.0305
15	.0104	45	.0312
16	.0111	46	.0319
17	.0118	47	.0326
18	.0125	48	.0333
19	.0131	49	.0340
20	.0138	50	.0347
21	.0145	51	.0354
22	.0152	52	.0361
23	.0159	53	.0368
24	.0166	54	.0375
25	.0173	55	.0381
26	.0180	56	.0388
27	.0187	57	.0395
28	.0194	58	.0402
29	.0201	59	.0409
30	.0208	60	.0416

To Interchange Degrees and Minutes of Longitude and Hours, Minutes, and Seconds of Time. Part 1

	0^h	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h
0^m	0°	15°	30°	45°	60°	75°	90°	105°	120°	135°	150°	165°
4	1	16	31	46	61	76	91	106	121	136	151	166
8	2	17	32	47	62	77	92	107	122	137	152	167
12	3	18	33	48	63	78	93	108	123	138	153	168
16	4	19	34	49	64	79	94	109	124	139	154	169
20	5	20	35	50	65	80	95	110	125	140	155	170
24	6	21	36	51	66	81	96	111	126	141	156	171
28	7	22	37	52	67	82	97	112	127	142	157	172
32	8	23	38	53	68	83	98	113	128	143	158	173
36	9	24	39	54	69	84	99	114	129	144	159	174
40	10	25	40	55	70	85	100	115	130	145	160	175
44	11	26	41	56	71	86	101	116	131	146	161	176
48	12	27	42	57	72	87	102	117	132	147	162	177
52	13	28	43	58	73	88	103	118	133	148	163	178
56	14	29	44	59	74	89	104	119	134	149	164	179

	12^h	13^h	14^h	15^h	16^h	17^h	18^h	19^h	20^h	21^h	22^h	23^h
0^m	180°	195°	210°	225°	240°	255°	270°	285°	300°	315°	330°	345°
4	181	196	211	226	241	256	271	286	301	316	331	346
8	182	197	212	227	242	257	272	287	302	317	332	347
12	183	198	213	228	243	258	273	288	303	318	333	348
16	184	199	214	229	244	259	274	289	304	319	334	349
20	185	200	215	230	245	260	275	290	305	320	335	350
24	186	201	216	231	246	261	276	291	306	321	336	351
28	187	202	217	232	247	262	277	292	307	322	337	352
32	188	203	218	233	248	263	278	293	308	323	338	353
36	189	204	219	234	249	264	279	294	309	324	339	354
40	190	205	220	235	250	265	280	295	310	325	340	355
44	191	206	221	236	251	266	281	296	311	326	341	356
48	192	207	222	237	252	267	282	297	312	327	342	357
52	193	208	223	238	253	268	283	298	313	328	343	358
56	194	209	224	239	254	269	284	299	314	329	344	359

Part 2

	0^m	1^m	2^m	3^m
0^s	0′	15′	30′	45′
4	1	16	31	46
8	2	17	32	47
12	3	18	33	48
16	4	19	34	49
20	5	20	35	50
24	6	21	36	51
28	7	22	37	52
32	8	23	38	53
36	9	24	39	54
40	10	25	40	55
44	11	26	41	56
48	12	27	42	57
52	13	28	43	58
56	14	29	44	59

Explanation of Table 9

1. To change degrees of longitude into hours and minutes of time: Find the number of degrees in Part 1. The required hours will then be found at the head of the column containing the degrees, and the required minutes at the left-hand end of the line containing the degrees.

Examples: $113° = 7^h\,32^m$; $294° = 19^h\,36^m$.

2. To change minutes of longitude into minutes and seconds of time: Find the minutes of longitude in Part 2. The required minutes and seconds of time will again be found at the head of the column and the left-hand end of the line.

Examples: $43' = 2^m\,52^s$; $28' = 1^m\,52^s$.

3. 1 and **2** can be combined by addition.

Examples: $113°\,43' = 7^h\,34^m\,52^s$.
$294°\,28' = 19^h\,37^m\,52^s$.

4. To change hours and minutes of time into degrees and minutes of longitude: Find the number of hours at the head of one of the columns of Part 1; then run down the column until you reach a line having at its left-hand end a number of minutes equal to (or just smaller than) the given number of minutes of time. Where that line and column meet you will find the required degrees of longitude.

Examples: $7^h\,32^m = 113°$; $19^h\,36^m = 294°$.

5. To change minutes and seconds of time into minutes of longitude: Find the number of minutes of time at the head of one of the columns of Part 2; then run down the column until you reach a line having at its left-hand end a number of seconds equal (or nearly equal) to the given number of seconds of time. Where that line and column meet you will find the minutes of longitude.

Examples: $2^m\,52^s = 43'$; $1^m\,52^s = 28'$.

6. 4 and **5** can be combined by addition:

Examples: $7^s\,34^m\,52^s = 113°\,43'$; $19^h\,37^m\,52^s = 294°\,28'$.

Table 10. Haversine Table

s	′	$0^h\,0^m$ Hav.	0° No.	$0^h\,4^m$ Hav.	1° No.	$0^h\,8^m$ Hav.	2° No.	$0^h\,12^m$ Hav.	3° No.
0	0		0.00000	5.88168	0.00008	6.48371	0.00030	6.83584	0.00069
4	1	2.32539	.00000	.89604	.00008	.49092	.00031	.84065	.00069
8	2	.92745	.00000	.91016	.00008	.49807	.00031	.84543	.00070
12	3	3.27963	.00000	.92406	.00008	.50516	.00032	.85019	.00071
16	4	.52951	.00000	.93774	.00009	.51219	.00033	.85492	.00072
20	5	3.72333	0.00000	5.95121	0.00009	6.51916	0.00033	6.85963	0.00072
24	6	.88169	.00000	.96447	.00009	.52608	.00034	.86431	.00073
28	7	4.01559	.00000	.97753	.00010	.53295	.00034	.86897	.00074
32	8	.13157	.00000	.99040	.00010	.53976	.00035	.87360	.00075
36	9	.23388	.00000	6.00308	.00010	.54652	.00035	.87821	.00076
40	10	4.32539	0.00000	6.01557	0.00010	6.55323	0.00036	6.88279	0.00076
44	11	.40818	.00000	.02789	.00011	.55988	.00036	.88735	.00077
48	12	.48375	.00000	.04004	.00011	.56649	.00037	.89188	.00078
52	13	.55328	.00000	.05202	.00011	.57304	.00037	.89639	.00079
56	14	.61765	.00000	.06384	.00012	.57955	.00038	.90088	.00080
s	′	$0^h\,1^m$	0°	$0^h\,5^m$	1°	$0^h\,9^m$	2°	$0^h\,13^m$	3°
0	15	4.67757	0.00000	6.07550	0.00012	6.58600	0.00039	6.90535	0.00080
4	16	.73363	.00001	.08700	.00012	.59241	.00039	.90979	.00081
8	17	.78629	.00001	.09836	.00013	.59878	.00040	.91421	.00082
12	18	.83594	.00001	.10956	.00013	.60509	.00040	.91860	.00083
16	19	.88290	.00001	.12063	.00013	.61136	.00041	.92298	.00084
20	20	4.92745	0.00001	6.13155	0.00014	6.61759	0.00041	6.92733	0.00085
24	21	.96983	.00001	.14234	.00014	.62377	.00042	.93166	.00085
28	22	5.01024	.00001	.15300	.00014	.62991	.00043	.93597	.00086
32	23	.04885	.00001	.16353	.00015	.63600	.00043	.94026	.00087
36	24	.08581	.00001	.17393	.00015	.64205	.00044	.94453	.00088
40	25	5.12127	0.00001	6.18421	0.00015	6.64806	0.00044	6.94877	0.00089
44	26	.15534	.00001	.19437	.00016	.65403	.00045	.95300	.00090
48	27	.18812	.00002	.20441	.00016	.65996	.00046	.95720	.00091
52	28	.21971	.00002	.21433	.00016	.66585	.00046	.96139	.00091
56	29	.25019	.00002	.22415	.00017	.67170	.00047	.96555	.00092
s	′	$0^h\,2^m$	0°	$0^h\,6^m$	1°	$0^h\,10^m$	2°	$0^h\,14^m$	3°
0	30	5.27963	0.00002	6.23385	0.00017	6.67751	0.00048	6.96970	0.00093
4	31	.30811	.00002	.24345	.00018	.68328	.00048	.97382	.00094
8	32	.33569	.00002	.25294	.00018	.68901	.00049	.97793	.00095
12	33	.36242	.00002	.26233	.00018	.69470	.00050	.98201	.00096
16	34	.38835	.00002	.27162	.00019	.70036	.00050	.98608	.00097
20	35	5.41352	0.00003	6.28081	0.00019	6.70598	0.00051	6.99013	0.00098
24	36	.43799	.00003	.28991	.00019	.71157	.00051	.99416	.00099
28	37	.46179	.00003	.29891	.00020	.71712	.00052	.99817	.00100
32	38	.48496	.00003	.30781	.00020	.72263	.00053	7.00216	.00101
36	39	.50752	.00003	.31663	.00021	.72811	.00053	.00613	.00101
40	40	5.52951	0.00003	6.32536	0.00021	6.73355	0.00054	7.01009	0.00102
44	41	.55095	.00004	.33400	.00022	.73896	.00055	.01403	.00103
48	42	.57189	.00004	.34256	.00022	.74434	.00056	.01795	.00104
52	43	.59232	.00004	.35103	.00022	.74969	.00056	.02185	.00105
56	44	.61229	.00004	.35943	.00023	.75500	.00057	.02573	.00106
s	′	$0^h\,3^m$	0°	$0^h\,7^m$	1°	$0^h\,11^m$	2°	$0^h\,15^m$	3°
0	45	5.63181	0.00004	6.36774	0.00023	6.76028	0.00058	7.02960	0.00107
4	46	.65090	.00004	.37597	.00024	.76552	.00058	.03345	.00108
8	47	.66958	.00005	.38412	.00024	.77074	.00059	.03729	.00109
12	48	.68787	.00005	.39220	.00025	.77592	.00060	.04110	.00110
16	49	.70578	.00005	.40021	.00025	.78108	.00060	.04490	.00111
20	50	5.72332	0.00005	6.40814	0.00026	6.78620	0.00061	7.04869	0.00112
24	51	.74052	.00006	.41600	.00026	.79129	.00062	.05245	.00113
28	52	.75739	.00006	.42379	.00027	.79630	.00063	.05620	.00114
32	53	.77394	.00006	.43151	.00027	.80139	.00063	.05994	.00115
36	54	.79017	.00006	.43916	.00027	.80640	.00064	.06366	.00116
40	55	5.80611	0.00006	6.44675	0.00028	6.81137	0.00065	7.06736	0.00117
44	56	.82176	.00007	.45427	.00028	.81632	.00066	.07105	.00118
48	57	.83713	.00007	.46172	.00029	.82124	.00066	.07472	.00119
52	58	.85224	.00007	.46911	.00029	.82614	.00067	.07837	.00120
56	59	.86709	.00007	.47644	.00030	.83100	.00068	.08201	.00121
60	60	5.88168	0.00008	6.48371	0.00030	6.83584	0.00069	7.08564	0.00122

s	′	$0^h\ 16^m$ Hav.	4° No.	$0^h\ 20^m$ Hav.	5° No.	$0^h\ 24^m$ Hav.	6° No.	$0^h\ 28^m$ Hav.	7° No.
0	0	7.08564	0.00122	7.27936	0.00190	7.43760	0.00274	7.57135	0.00373
4	1	.08925	.00123	.28225	.00192	.44001	.00275	.57341	.00374
8	2	.09284	.00124	.28513	.00193	.44241	.00277	.57547	.00376
12	3	.09642	.00125	.28800	.00194	.44480	.00278	.57752	.00378
16	4	.09999	.00126	.29086	.00195	.44719	.00280	.57957	.00380
20	5	7.10354	0.00127	7.29371	0.00197	7.44957	0.00282	7.58162	0.00382
24	6	.10708	.00128	.29655	.00198	.45194	.00283	.58366	.00383
28	7	.11060	.00129	.29938	.00199	.45431	.00285	.58569	.00385
32	8	.11411	.00130	.30220	.00201	.45667	.00286	.58772	.00387
36	9	.11760	.00131	.30502	.00202	.45903	.00288	.58974	.00389
40	10	7.12108	0.00132	7.30782	0.00203	7.46138	0.00289	7.59176	0.00391
44	11	.12455	.00133	.31062	.00204	.46372	.00291	.59378	.00392
48	12	.12800	.00134	.31340	.00206	.46605	.00292	.59579	.00394
52	13	.13144	.00135	.31618	.00207	.46838	.00294	.59779	.00396
56	14	.13486	.00136	.31895	.00208	.47071	.00296	.59979	.00398
s	′	$0^h\ 17^m$	4°	$0^h\ 21^m$	5°	$0^h\ 25^m$	6°	$0^h\ 29^m$	7°
0	15	7.13827	0.00137	7.32171	0.00210	7.47302	0.00297	7.60179	0.00400
4	16	.14167	.00139	.32446	.00211	.47533	.00299	.60378	.00402
8	17	.14506	.00140	.32720	.00212	.47764	.00300	.60577	.00403
12	18	.14843	.00141	.32994	.00214	.47994	.00302	.60775	.00405
16	19	.15179	.00142	.33266	.00215	.48223	.00304	.60973	.00407
20	20	7.15513	0.00143	7.33538	0.00216	7.48452	0.00305	7.61170	0.00409
24	21	.15846	.00144	.33809	.00218	.48680	.00307	.61367	.00411
28	22	.16178	.00145	.34079	.00219	.48907	.00308	.61564	.00413
32	23	.16509	.00146	.34348	.00221	.49134	.00310	.61760	.00415
36	24	.16839	.00147	.34616	.00222	.49360	.00312	.61955	.00416
40	25	7.17167	0.00148	7.34884	0.00223	7.49586	0.00313	7.62151	0.00418
44	26	.17494	.00150	.35150	.00225	.49811	.00315	.62345	.00420
48	27	.17820	.00151	.35416	.00226	.50036	.00316	.62540	.00422
52	28	.18144	.00152	.35681	.00227	.50259	.00318	.62733	.00424
56	29	.18468	.00153	.35945	.00229	.50483	.00320	.62927	.00426
s	′	$0^h\ 18^m$	4°	$0^h\ 22^m$	5°	$0^h\ 26^m$	6°	$0^h\ 30^m$	7°
0	30	7.18790	0.00154	7.36209	0.00230	7.50706	0.00321	7.63120	0.00428
4	31	.19111	.00155	.36471	.00232	.50928	.00323	.63312	.00430
8	32	.19430	.00156	.36733	.00233	.51149	.00325	.63504	.00432
12	33	.19749	.00158	.36994	.00234	.51370	.00326	.63696	.00433
16	34	.20066	.00159	.37254	.00236	.51591	.00328	.63887	.00435
20	35	7.20383	0.00160	7.37514	0.00237	7.51811	0.00330	7.64078	0.00437
24	36	.20698	.00161	.37773	.00239	.52030	.00331	.64269	.00439
28	37	.21012	.00162	.38030	.00240	.52249	.00333	.64458	.00441
32	38	.21325	.00163	.38288	.00241	.52467	.00335	.64648	.00443
36	39	.21636	.00165	.38544	.00243	.52685	.00336	.64837	.00445
40	40	7.21947	0.00166	7.38800	0.00244	7.52902	0.00338	7.65026	0.00447
44	41	.22256	.00167	.39054	.00246	.53119	.00340	.65214	.00449
48	42	.22565	.00168	.39309	.00247	.53335	.00341	.65402	.00451
52	43	.22872	.00169	.39562	.00249	.53550	.00343	.65590	.00453
56	44	.23178	.00171	.39815	.00250	.53766	.00345	.65777	.00455
s	′	$0^h\ 19^m$	4°	$0^h\ 23^m$	5°	$0^h\ 27^m$	6°	$0^h\ 31^m$	7°
0	45	7.23483	0.00172	7.40067	0.00252	7.53980	0.00347	7.65964	0.00457
4	46	.23787	.00173	.40318	.00253	.54194	.00348	.66150	.00459
8	47	.24090	.00174	.40568	.00255	.54407	.00350	.66336	.00461
12	48	.24392	.00175	.40818	.00256	.54620	.00352	.66521	.00463
16	49	.24693	.00177	.41067	.00257	.54833	.00353	.66706	.00465
20	50	7.24993	0.00178	7.41315	0.00259	7.55045	0.00355	7.66891	0.00467
24	51	.25292	.00179	.41563	.00260	.55256	.00357	.67075	.00469
28	52	.25590	.00180	.41810	.00262	.55467	.00359	.67259	.00471
32	53	.25886	.00181	.42056	.00263	.55677	.00360	.67443	.00473
36	54	.26182	.00183	.42301	.00265	.55887	.00362	.67626	.00475
40	55	7.26477	0.00184	7.42546	0.00266	7.56096	0.00364	7.67809	0.00477
44	56	.26771	.00185	.42790	.00268	.56305	.00366	.67991	.00479
48	57	.27064	.00186	.43034	.00269	.56513	.00367	.68173	.00481
52	58	.27355	.00188	.43277	.00271	.56721	.00369	.68355	.00483
56	59	.27646	.00189	.43519	.00272	.56928	.00371	.68536	.00485
60	60	7.27936	0.00190	7.43760	0.00274	7.57135	0.00373	7.68717	0.00487

s	′	0h 32m Hav.	8° No.	0h 36m Hav.	9° No.	0h 40m Hav.	10° No.	0h 44m Hav.	11° No.
0	0	7.68717	0.00487	7.78929	0.00616	7.88059	0.00760	7.96315	0.00919
4	1	.68897	.00489	.79089	.00618	.88203	.00762	.96446	.00921
8	2	.69077	.00491	.79249	.00620	.88348	.00765	.96577	.00924
12	3	.69257	.00493	.79409	.00622	.88491	.00767	.96707	.00927
16	4	.69437	.00495	.79568	.00625	.88635	.00770	.96838	.00930
20	5	7.69616	0.00497	7.79728	0.00627	7.88778	0.00772	7.96968	0.00933
24	6	.69794	.00499	.79886	.00629	.88921	.00775	.97098	.00935
28	7	.69972	.00501	.80045	.00632	.89064	.00777	.97228	.00938
32	8	.70150	.00503	.80203	.00634	.89207	.00780	.97358	.00941
36	9	.70328	.00505	.80361	.00636	.89349	.00783	.97478	.00944
40	10	7.70505	0.00507	7.80519	0.00639	7.89491	0.00785	7.97617	0.00947
44	11	.70682	.00509	.80677	.00641	.89633	.00788	.97746	.00949
48	12	.70858	.00511	.80834	.00643	.89775	.00790	.97875	.00952
52	13	.71034	.00513	.80991	.00646	.89916	.00793	.98003	.00955
56	14	.71210	.00515	.81147	.00648	.90057	.00795	.98132	.00958
s	′	0h 33m	8°	0h 37m	9°	0h 41m	10°	0h 45m	11°
0	15	7.71385	0.00517	7.81303	0.00650	7.90198	0.00798	7.98260	0.00961
4	16	.71560	.00520	.81459	.00653	.90339	.00801	.98389	.00964
8	17	.71735	.00522	.81615	.00655	.90480	.00803	.98517	.00966
12	18	.71909	.00524	.81771	.00657	.90620	.00806	.98644	.00969
16	19	.72083	.00526	.81926	.00660	.90760	.00808	.98772	.00972
20	20	7.72257	0.00528	7.82081	0.00662	7.90900	0.00811	7.98899	0.00975
24	21	.72430	.00530	.82235	.00664	.91039	.00814	.99027	.00978
28	22	.72603	.00532	.82390	.00667	.91179	.00816	.99154	.00981
32	23	.72775	.00534	.82544	.00669	.91318	.00819	.99281	.00984
36	24	.72948	.00536	.82698	.00671	.91457	.00821	.99407	.00986
40	25	7.73119	0.00539	7.82851	0.00674	7.91596	0.00824	7.99534	0.00989
44	26	.73291	.00541	.83004	.00676	.91734	.00827	.99660	.00992
48	27	.73462	.00543	.83157	.00679	.91872	.00829	.99786	.00995
52	28	.73633	.00545	.83310	.00681	.92010	.00832	.99912	.00998
56	29	.73803	.00547	.83463	.00683	.92148	.00835	8.00038	.01001
s	′	0h 34m	8°	0h 38m	9°	0h 42m	10°	0h 46m	11°
0	30	7.73974	0.00549	7.83615	0.00686	7.92286	0.00837	8.00163	0.01004
4	31	.74143	.00551	.83767	.00688	.92423	.00840	.00289	.01007
8	32	.74313	.00554	.83918	.00691	.92560	.00843	.00414	.01010
12	33	.74482	.00556	.84070	.00693	.92697	.00846	.00539	.01012
16	34	.74651	.00558	.84221	.00695	.92834	.00848	.00664	.01015
20	35	7.74819	0.00560	7.84372	0.00698	7.92970	0.00851	8.00788	0.01018
24	36	.74988	.00562	.84522	.00700	.93107	.00853	.00913	.01021
28	37	.75155	.00564	.84672	.00703	.93243	.00856	.01037	.01024
32	38	.75323	.00567	.84822	.00705	.93379	.00859	.01161	.01027
36	39	.75490	.00569	.84972	.00707	.93514	.00861	.01285	.01030
40	40	7.75657	0.00571	7.85122	0.00710	7.93650	0.00864	8.01409	0.01033
44	41	.75824	.00573	.85271	.00712	.93785	.00867	.01532	.01036
48	42	.75990	.00575	.85420	.00715	.93920	.00869	.01656	.01039
52	43	.76156	.00578	.85569	.00717	.94055	.00872	.01779	.01042
56	44	.76321	.00580	.85717	.00720	.94189	.00875	.01902	.01045
s	′	0h 35m	8°	0h 39m	9°	0h 43m	10°	0h 47m	11°
0	45	7.76487	0.00582	7.85866	0.00722	7.94324	0.00877	8.02025	0.01048
4	46	.76652	.00584	.86014	.00725	.94458	.00880	.02148	.01051
8	47	.76816	.00586	.86161	.00727	.94592	.00883	.02270	.01054
12	48	.76981	.00589	.86309	.00730	.94726	.00886	.02392	.01057
16	49	.77145	.00591	.86456	.00732	.94859	.00888	.02515	.01060
20	50	7.77308	0.00593	7.86603	0.00735	7.94992	0.00891	8.02637	0.01063
24	51	.77472	.00595	.86750	.00737	.95126	.00894	.02758	.01066
28	52	.77635	.00598	.86896	.00740	.95259	.00897	.02880	.01069
32	53	.77798	.00600	.87042	.00742	.95391	.00899	.03001	.01072
36	54	.77960	.00602	.87188	.00745	.95524	.00902	.03123	.01075
40	55	7.78122	0.00604	7.87334	0.00747	7.95656	0.00905	8.03244	0.01078
44	56	.78284	.00607	.87480	.00750	.95788	.00908	.03365	.01081
48	57	.78446	.00609	.87625	.00752	.95920	.00910	.03486	.01084
52	58	.78607	.00611	.87770	.00755	.96052	.00913	.03606	.01087
56	59	.78768	.00613	.87915	.00757	.96183	.00916	.03727	.01090
60	60	7.78929	0.00616	7.88059	0.00760	7.96315	0.00919	8.03847	0.01093

s	'	0h 48m	12°	0h 52m	13°	0h 56m	14°	1h 0m	15°
		Hav.	No.	Hav.	No.	Hav.	No.	Hav.	No.
0	0	8.03847	0.01093	8.10772	0.01282	8.17179	0.01485	8.23140	0.01704
4	1	.03967	.01096	.10883	.01285	.17282	.01489	.23235	.01707
8	2	.04087	.01099	.10993	.01288	.17384	.01492	.23331	.01711
12	3	.04207	.01102	.11104	.01291	.17487	.01496	.23427	.01715
16	4	.04326	.01105	.11214	.01295	.17590	.01499	.23523	.01719
20	5	8.04446	0.01108	8.11324	0.01298	8.17692	0.01503	8.23618	0.01723
24	6	.04565	.01111	.11435	.01301	.17794	.01506	.23713	.01726
28	7	.04684	.01114	.11544	.01305	.17896	.01510	.23809	.01730
32	8	.04803	.01117	.11654	.01308	.17998	.01513	.23904	.01734
36	9	.04922	.01120	.11764	.01311	.18100	.01517	.23999	.01738
40	10	8.05041	0.01123	8.11873	0.01314	8.18202	0.01521	8.24094	0.01742
44	11	.05159	.01126	.11983	.01317	.18303	.01524	.24189	.01745
48	12	.05277	.01129	.12092	.01321	.18405	.01528	.24283	.01749
52	13	.05395	.01132	.12201	.01324	.18506	.01531	.24378	.01753
56	14	.05513	.01135	.12310	.01328	.18607	.01535	.24473	.01757
s	'	0h 49m	12°	0h 53m	13°	0h 57m	14°	1h 1m	15°
0	15	8.05631	0.01138	8.12419	0.01331	8.18709	0.01538	8.24567	0.01761
4	16	.05749	.01142	.12528	.01334	.18810	.01542	.24661	.01764
8	17	.05866	.01145	.12636	.01338	.18910	.01546	.24755	.01768
12	18	.05984	.01148	.12745	.01341	.19011	.01549	.24850	.01772
16	19	.06101	.01151	.12853	.01344	.19112	.01553	.24944	.01776
20	20	8.06218	0.01154	8.12961	0.01348	8.19212	0.01556	8.25037	0.01780
24	21	.06335	.01157	.13069	.01351	.19313	.01560	.25131	.01784
28	22	.06451	.01160	.13177	.01354	.19413	.01564	.25225	.01788
32	23	.06568	.01163	.13285	.01358	.19513	.01567	.25319	.01791
36	24	.06684	.01166	.13392	.01361	.19613	.01571	.25412	.01795
40	25	8.06800	0.01170	8.13500	0.01365	8.19713	0.01574	8.25505	0.01799
44	26	.06917	.01173	.13607	.01368	.19813	.01578	.25599	.01803
48	27	.07032	.01176	.13714	.01371	.19913	.01582	.25692	.01807
52	28	.07148	.01179	.13822	.01375	.20012	.01585	.25785	.01811
56	29	.07264	.01182	.13928	.01378	.20112	.01589	.25878	.01815
s	'	0h 50m	12°	0h 54m	13°	0h 58m	14°	1h 2m	15°
0	30	8.07379	0.01185	8.14035	0.01382	8.20211	0.01593	8.25971	0.01818
4	31	.07494	.01188	.14142	.01385	.20310	.01596	.26064	.01822
8	32	.07610	.01192	.14248	.01388	.20410	.01600	.26156	.01826
12	33	.07725	.01195	.14355	.01392	.20509	.01604	.26249	.01830
16	34	.07839	.01198	.14461	.01395	.20608	.01607	.26341	.01834
20	35	8.07954	0.01201	8.14567	0.01399	8.20706	0.01611	8.26434	0.01838
24	36	.08069	.01204	.14673	.01402	.20805	.01615	.26526	.01842
28	37	.08183	.01207	.14779	.01405	.20904	.01618	.26618	.01846
32	38	.08297	.01211	.14885	.01409	.21002	.01622	.26710	.01850
36	39	.08411	.01214	.14991	.01412	.21100	.01626	.26802	.01854
40	40	8.08525	0.01217	8.15096	0.01416	8.21199	0.01629	8.26894	0.01858
44	41	.08639	.01220	.15201	.01419	.21297	.01633	.26986	.01861
48	42	.08752	.01223	.15307	.01423	.21395	.01637	.27078	.01865
52	43	.08866	.01226	.15412	.01426	.21493	.01640	.27169	.01869
56	44	.08979	.01230	.15517	.01429	.21590	.01644	.27261	.01873
s	'	0h 51m	12°	0h 55m	13°	0h 59m	14°	1h 3m	15°
0	45	8.09092	0.01233	8.15622	0.01433	8.21688	0.01648	8.27352	0.01877
4	46	.09205	.01236	.15726	.01436	.21785	.01651	.27443	.01881
8	47	.09318	.01239	.15831	.01440	.21883	.01655	.27534	.01885
12	48	.09431	.01243	.15935	.01443	.21980	.01659	.27626	.01889
16	49	.09543	.01246	.16040	.01447	.22077	.01663	.27717	.01893
20	50	8.09656	0.01249	8.16144	0.01450	8.22175	0.01666	8.27807	0.01897
24	51	.09768	.01252	.16248	.01454	.22272	.01670	.27898	.01901
28	52	.09880	.01255	.16352	.01457	.22368	.01674	.27989	.01905
32	53	.09992	.01259	.16456	.01461	.22465	.01677	.28080	.01909
36	54	.10104	.01262	.16559	.01464	.22562	.01681	.28170	.01913
40	55	8.10216	0.01265	8.16663	0.01468	8.22658	0.01685	8.28260	0.01917
44	56	.10327	.01268	.16766	.01471	.22755	.01689	.28351	.01921
48	57	.10439	.01272	.16870	.01475	.22851	.01692	.28441	.01925
52	58	.10550	.01275	.16973	.01478	.22947	.01696	.28531	.01929
56	59	.10661	.01278	.17076	.01482	.23044	.01700	.28621	.01933
60	60	8.10772	0.01282	8.17179	0.01485	8.23140	0.01704	8.28711	0.01937

s	′	$1^h\ 4^m$	16°	$1^h\ 8^m$	17°	$1^h\ 12^m$	18°	$1^h\ 16^m$	19°
		Hav.	No.	Hav.	No.	Hav.	No.	Hav.	No.
0	0	8.28711	0.01937	8.33940	0.02185	8.38867	0.02447	8.43522	0.02724
4	1	.28801	.01941	.34025	.02189	.38946	.02452	.43597	.02729
8	2	.28891	.01945	.34109	.02193	.39026	.02456	.43673	.02734
12	3	.28980	.01949	.34194	.02198	.39105	.02461	.43748	.02738
16	4	.29070	.01953	.34278	.02202	.39185	.02465	.43823	.02743
20	5	8.29159	0.01957	8.34362	0.02206	8.39264	0.02470	8.43899	0.02748
24	6	.29249	.01961	.34446	.02210	.39344	.02474	.43974	.02753
28	7	.29338	.01965	.34530	.02215	.39423	.02479	.44049	.02757
32	8	.29427	.01969	.34614	.02219	.39502	.02483	.44124	.02762
36	9	.29516	.01973	.34698	.02223	.39581	.02488	.44199	.02767
40	10	8.29605	0.01977	8.34782	0.02227	8.39660	0.02492	8.44273	0.02772
44	11	.29694	.01981	.34865	.02232	.39739	.02497	.44348	.02776
48	12	.29783	.01985	.34949	.02236	.39818	.02501	.44423	.02781
52	13	.29872	.01989	.35032	.02240	.39897	.02506	.44498	.02786
56	14	.29960	.01993	.35116	.02245	.39976	.02510	.44572	.02791
s	′	$1^h\ 5^m$	16°	$1^h\ 9^m$	17°	$1^h\ 13^m$	18°	$1^h\ 17^m$	19°
0	15	8.30049	0.01998	8.35199	0.02249	8.40055	0.02515	8.44647	0.02796
4	16	.30137	.02002	.35282	.02253	.40133	.02520	.44721	.02800
8	17	.30226	.02006	.35365	.02258	.40212	.02524	.44796	.02805
12	18	.30314	.02010	.35449	.02262	.40290	.02529	.44870	.02810
16	19	.30402	.02014	.35532	.02266	.40369	.02533	.44944	.02815
20	20	8.30490	0.02018	8.35614	0.02271	8.40447	0.02538	8.45018	0.02820
24	21	.30578	.02022	.35697	.02275	.40525	.02542	.45093	.02824
28	22	.30666	.02026	.35780	.02279	.40603	.02547	.45167	.02829
32	23	.30754	.02030	.35863	.02284	.40681	.02552	.45241	.02834
36	24	.30842	.02034	.35945	.02288	.40760	.02556	.45315	.02839
40	25	8.30929	0.02038	8.36028	0.02292	8.40837	0.02561	8.45388	0.02844
44	26	.31017	.02043	.36110	.02297	.40915	.02565	.45462	.02849
48	27	.31104	.02047	.36193	.02301	.40993	.02570	.45536	.02853
52	28	.31192	.02051	.36275	.02305	.41071	.02575	.45610	.02858
56	29	.31279	.02055	.36357	.02310	.41149	.02579	.45683	.02863
s	′	$1^h\ 6^m$	16°	$1^h\ 10^m$	17°	$1^h\ 14^m$	18°	$1^h\ 18^m$	19°
0	30	8.31366	0.02059	8.36439	0.02314	8.41226	0.02584	8.45757	0.02868
4	31	.31453	.02063	.36521	.02319	.41304	.02588	.45830	.02873
8	32	.31540	.02067	.36603	.02323	.41381	.02593	.45904	.02878
12	33	.31627	.02071	.36685	.02327	.41459	.02598	.45977	.02883
16	34	.31714	.02076	.36767	.02332	.41536	.02602	.46050	.02887
20	35	8.31800	0.02080	8.36849	0.02336	8.41613	0.02607	8.46124	0.02892
24	36	.31887	.02084	.36930	.02340	.41690	.02612	.46197	.02897
28	37	.31974	.02088	.37012	.02345	.41767	.02616	.46270	.02902
32	38	.32060	.02092	.37093	.02349	.41845	.02621	.46343	.02907
36	39	.32147	.02096	.37175	.02354	.41921	.02626	.46416	.02912
40	40	8.32233	0.02101	8.37256	0.02358	8.41998	0.02630	8.46489	0.02917
44	41	.32319	.02105	.37337	.02363	.42075	.02635	.46562	.02922
48	42	.32405	.02109	.37419	.02367	.42152	.02639	.46634	.02926
52	43	.32491	.02113	.37500	.02371	.42229	.02644	.46707	.02931
56	44	.32577	.02117	.37581	.02376	.42305	.02649	.46780	.02936
s	′	$1^h\ 7^m$	16°	$1^h\ 11^m$	17°	$1^h\ 15^m$	18°	$1^h\ 19^m$	19°
0	45	8.32663	0.02121	8.37662	0.02380	8.42382	0.02653	8.46852	0.02941
4	46	.32749	.02126	.37742	.02385	.42458	.02658	.46925	.02946
8	47	.32834	.02130	.37823	.02389	.42535	.02663	.46998	.02951
12	48	.32920	.02134	.37904	.02394	.42611	.02668	.47070	.02956
16	49	.33006	.02138	.37985	.02398	.42687	.02672	.47142	.02961
20	50	8.33091	0.02142	8.38065	0.02402	8.42764	0.02677	8.47215	0.02966
24	51	.33176	.02147	.38146	.02407	.42840	.02682	.47287	.02971
28	52	.33262	.02151	.38226	.02411	.42916	.02686	.47359	.02976
32	53	.33347	.02155	.38306	.02416	.42992	.02691	.47431	.02981
36	54	.33432	.02159	.38387	.02420	.43068	.02696	.47503	.02986
40	55	8.33517	0.02164	8.38467	0.02425	8.43144	0.02700	8.47575	0.02991
44	56	.33602	.02168	.38547	.02429	.43219	.02705	.47647	.02996
48	57	.33686	.02172	.38627	.02434	.43295	.02710	.47719	.03000
52	58	.33771	.02176	.38707	.02438	.43371	.02715	.47791	.03005
56	59	.33856	.02181	.38787	.02443	.43446	.02719	.47862	.03010
60	60	8.33940	0.02185	8.38867	0.02447	8.43522	0.02724	8.47934	0.03015

s	′	$1^h\ 20^m$ Hav.	20° No.	$1^h\ 24^m$ Hav.	21° No.	$1^h\ 28^m$ Hav.	22° No.	$1^h\ 32^m$ Hav.	23° No.
0	**0**	8.47934	**0.03015**	8.52127	**0.03321**	8.56120	**0.03641**	8.59931	**0.03975**
4	**1**	.48006	**.03020**	.52195	**.03326**	.56185	**.03646**	.59993	**.03980**
8	**2**	.48077	**.03025**	.52263	**.03331**	.56250	**.03652**	.60055	**.03986**
12	**3**	.48149	**.03030**	.52331	**.03337**	.56315	**.03657**	.60117	**.03992**
16	**4**	.48220	**.03035**	.52399	**.03342**	.56379	**.03663**	.60179	**.03998**
20	**5**	8.48292	**0.03040**	8.52467	**0.03347**	8.56444	**0.03668**	8.60241	**0.04003**
24	**6**	.48363	**.03045**	.52535	**.03352**	.56509	**.03674**	.60303	**.04009**
28	**7**	.48434	**.03050**	.52602	**.03368**	.56574	**.03679**	.60365	**.04015**
32	**8**	.48505	**.03055**	.52670	**.03363**	.56638	**.03685**	.60426	**.04020**
36	**9**	.48576	**.03060**	.52738	**.03368**	.56703	**.03690**	.60488	**.04026**
40	**10**	8.48648	**0.03065**	8.52806	**0.03373**	8.56767	**0.03695**	8.60550	**0.04032**
44	**11**	.48719	**.03070**	.52873	**.03379**	.56832	**.03701**	.60611	**.04038**
48	**12**	.48789	**.03075**	.52941	**.03384**	.56896	**.03706**	.60673	**.04043**
52	**13**	.48860	**.03080**	.53008	**.03389**	.56960	**.03712**	.60734	**.04049**
56	**14**	.48931	**.03085**	.53076	**.03394**	.57025	**.03717**	.60796	**.04055**
s	′	$1^h\ 21^m$	20°	$1^h\ 25^m$	21°	$1^h\ 29^m$	22°	$1^h\ 33^m$	23°
0	**15**	8.49002	**0.03090**	8.53143	**0.03400**	8.57089	**0.03723**	8.60857	**0.04060**
4	**16**	.49073	**.03095**	.53210	**.03405**	.57153	**.03728**	.60919	**.04066**
8	**17**	.49143	**.03101**	.53277	**.03410**	.57217	**.03734**	.60980	**.04072**
12	**18**	.49214	**.03106**	.53345	**.03415**	.57282	**.03740**	.61041	**.04078**
16	**19**	.49284	**.03111**	.53412	**.03421**	.57346	**.03745**	.61103	**.04083**
20	**20**	8.49355	**0.03116**	8.53479	**0.03426**	8.57410	**0.03751**	8.61164	**0.04089**
24	**21**	.49425	**.03121**	.53546	**.03431**	.57474	**.03756**	.61225	**.04095**
28	**22**	.49496	**.03126**	.53613	**.03437**	.57538	**.03762**	.61286	**.04101**
32	**23**	.49566	**.03131**	.53680	**.03442**	.57601	**.03767**	.61347	**.04106**
36	**24**	.49636	**.03136**	.53747	**.03447**	.57665	**.03773**	.61408	**.04112**
40	**25**	8.49706	**0.03141**	8.53814	**0.03453**	8.57729	**0.03778**	8.61469	**0.04118**
44	**26**	.49777	**.03146**	.53880	**.03458**	.57793	**.03784**	.61530	**.04124**
48	**27**	.49847	**.03151**	.53947	**.03463**	.57856	**.03789**	.61591	**.04130**
52	**28**	.49917	**.03156**	.54014	**.03468**	.57920	**.03795**	.61652	**.04135**
56	**29**	.49987	**.03161**	.54080	**.03474**	.57984	**.03800**	.61713	**.04141**
s	′	$1^h\ 22^m$	20°	$1^h\ 26^m$	21°	$1^h\ 30^m$	22°	$1^h\ 34^m$	23°
0	**30**	8.50056	**0.03166**	8.54147	**0.03479**	8.58047	**0.03806**	8.61773	**0.04147**
4	**31**	.50126	**.03171**	.54214	**.03484**	.58111	**.03812**	.61834	**.04153**
8	**32**	.50196	**.03177**	.54280	**.03490**	.58174	**.03817**	.61895	**.04159**
12	**33**	.50266	**.03182**	.54346	**.03495**	.58238	**.03823**	.61955	**.04164**
16	**34**	.50335	**.03187**	.54413	**.03500**	.58301	**.03828**	.62016	**.04170**
20	**35**	8.50405	**0.03192**	8.54479	**0.03506**	8.58364	**0.03834**	8.62077	**0.04176**
24	**36**	.50475	**.03197**	.54545	**.03511**	.58427	**.03839**	.62137	**.04182**
28	**37**	.50544	**.03202**	.54612	**.03517**	.58491	**.03845**	.62197	**.04188**
32	**38**	.50614	**.03207**	.54678	**.03522**	.58554	**.03851**	.62258	**.04194**
36	**39**	.50683	**.03212**	.54744	**.03527**	.58617	**.03856**	.62318	**.04199**
40	**40**	8.50752	**0.03218**	8.54810	**0.03533**	8.58680	**0.03862**	8.62379	**0.04205**
44	**41**	.50821	**.03223**	.54876	**.03538**	.58743	**.03867**	.62439	**.04211**
48	**42**	.50891	**.03228**	.54942	**.03543**	.58806	**.03873**	.62499	**.04217**
52	**43**	.50960	**.03233**	.55008	**.03549**	.58869	**.03879**	.62559	**.04223**
56	**44**	.51029	**.03238**	.55073	**.03554**	.58932	**.03884**	.62619	**.04229**
s	′	$1^h\ 23^m$	20°	$1^h\ 27^m$	21°	$1^h\ 31^m$	22°	$1^h\ 35^m$	23°
0	**46**	8.51098	**0.03243**	8.55139	**0.03560**	8.58994	**0.03890**	8.62680	**0.04234**
4	**46**	.51167	**.03248**	.55205	**.03565**	.59057	**.03896**	.62740	**.04240**
8	**47**	.51236	**.03264**	.55271	**.03570**	.59120	**.03901**	.62800	**.04246**
12	**48**	.51305	**.03269**	.55336	**.03576**	.59183	**.03907**	.62860	**.04252**
16	**49**	.51374	**.03264**	.55402	**.03581**	.59245	**.03912**	.62919	**.04258**
20	**60**	8.51442	**0.03269**	8.55467	**0.03587**	8.59308	**0.03918**	8.62979	**0.04264**
24	**61**	.51511	**.03274**	.55533	**.03592**	.59370	**.03924**	.63039	**.04270**
28	**52**	.51580	**.03279**	.55598	**.03597**	.59433	**.03929**	.63099	**.04276**
32	**53**	.51648	**.03285**	.55664	**.03603**	.59495	**.03935**	.63159	**.04281**
36	**64**	.51717	**.03290**	.55729	**.03608**	.59558	**.03941**	.63218	**.04287**
40	**66**	8.51785	**0.03295**	8.55794	**0.03614**	8.59620	**0.03946**	8.63278	**0.04293**
44	**66**	.51854	**.03300**	.55859	**.03619**	.59682	**.03952**	.63338	**.04299**
48	**57**	.51922	**.03305**	.55925	**.03624**	.59745	**.03958**	.63397	**.04305**
52	**58**	.51990	**.03311**	.55990	**.03630**	.59807	**.03963**	.63457	**.04311**
56	**59**	.52058	**.03316**	.56055	**.03635**	.59869	**.03969**	.63516	**.04317**
60	**66**	8.52127	**0.03321**	8.56120	**0.03641**	8.59931	**0.03975**	8.63576	**0.04323**

s	′	1h 36m Hav.	24° No.	1h 40m Hav.	25° No.	1h 44m Hav.	26° No.	1h 48m Hav.	27° No.
0	0	8.63576	0.04323	8.67067	0.04685	8.70418	0.05060	8.73637	0.05450
4	1	.63635	.04329	.67124	.04691	.70472	.05067	.73690	.05456
8	2	.63695	.04335	.67181	.04697	.70527	.05073	.73742	.05463
12	3	.63754	.04340	.67238	.04703	.70582	.05079	.73795	.05470
16	4	.63813	.04346	.67295	.04709	.70636	.05086	.73847	.05476
20	5	8.63872	0.04352	8.67352	0.04715	8.70691	0.05092	8.73900	0.05483
24	6	.63932	.04358	.67409	.04722	.70745	.05099	.73952	.05489
28	7	.63991	.04364	.67465	.04728	.70800	.05105	.74005	.05496
32	8	.64050	.04370	.67522	.04734	.70854	.05111	.74057	.05503
36	9	.64109	.04376	.67579	.04740	.70909	.05118	.74109	.05509
40	10	8.64168	0.04382	8.67635	0.04746	8.70963	0.05124	8.74162	0.05516
44	11	.64227	.04388	.67692	.04752	.71017	.05131	.74214	.05523
48	12	.64286	.04394	.67748	.04759	.71072	.05137	.74266	.05529
52	13	.64345	.04400	.67805	.04765	.71126	.05144	.74318	.05536
56	14	.64404	.04406	.67861	.04771	.71180	.05150	.74371	.05542
s	′	1h 37m	24°	1h 41m	25°	1h 45m	26°	1h 49m	27°
0	15	8.64463	0.04412	8.67918	0.04777	8.71234	0.05156	8.74423	0.05549
4	16	.64521	.04418	.67974	.04783	.71289	.05163	.74475	.05556
8	17	.64580	.04424	.68030	.04790	.71343	.05169	.74527	.05562
12	18	.64639	.04430	.68087	.04796	.71397	.05176	.74579	.05569
16	19	.64697	.04436	.68143	.04802	.71451	.05182	.74631	.05576
20	20	8.64756	0.04442	8.68199	0.04808	8.71505	0.05189	8.74683	0.05582
24	21	.64815	.04448	.68256	.04815	.71559	.05195	.74735	.05589
28	22	.64873	.04454	.68312	.04821	.71613	.05201	.74787	.05596
32	23	.64932	.04460	.68368	.04827	.71667	.05208	.74839	.05603
36	24	.64990	.04466	.68424	.04833	.71721	.05214	.74890	.05609
40	25	8.65049	0.04472	8.68480	0.04839	8.71774	0.05221	8.74942	0.05616
44	26	.65107	.04478	.68536	.04846	.71828	.05227	.74994	.05623
48	27	.65165	.04484	.68592	.04852	.71882	.05234	.75046	.05629
52	28	.65224	.04490	.68648	.04858	.71936	.05240	.75097	.05636
56	29	.65282	.04496	.68704	.04864	.71989	.05247	.75149	.05643
s	′	1h 38m	24°	1h 42m	25°	1h 46m	26°	1h 50m	27°
0	30	8.65340	0.04502	8.68760	0.04871	8.72043	0.05253	8.75201	0.05649
4	31	.65398	.04508	.68815	.04877	.72097	.05260	.75252	.05656
8	32	.65456	.04514	.68871	.04883	.72150	.05266	.75304	.05663
12	33	.65514	.04520	.68927	.04890	.72204	.05273	.75355	.05670
16	34	.65572	.04526	.68983	.04896	.72257	.05279	.75407	.05676
20	35	8.65630	0.04532	8.69038	0.04902	8.72311	0.05286	8.75458	0.05683
24	36	.65688	.04538	.69094	.04908	.72364	.05292	.75510	.05690
28	37	.65746	.04544	.69149	.04915	.72418	.05299	.75561	.05697
32	38	.65804	.04550	.69205	.04921	.72471	.05305	.75613	.05703
36	39	.65862	.04556	.69260	.04927	.72525	.05312	.75664	.05710
40	40	8.65920	0.04562	8.69316	0.04934	8.72578	0.05318	8.75715	0.05717
44	41	.65978	.04569	.69371	.04940	.72631	.05325	.75767	.05724
48	42	.66035	.04575	.69427	.04946	.72684	.05331	.75818	.05730
52	43	.66093	.04581	.69482	.04952	.72738	.05338	.75869	.05737
56	44	.66151	.04587	.69537	.04959	.72791	.05345	.75920	.05744
s	′	1h 39m	24°	1h 43m	25°	1h 47m	26°	1h 51m	27°
0	45	8.66208	0.04593	8.69593	0.04965	8.72844	0.05351	8.75972	0.05751
4	46	.66266	.04599	.69648	.04971	.72897	.05358	.76023	.05757
8	47	.66323	.04605	.69703	.04978	.72950	.05364	.76074	.05764
12	48	.66381	.04611	.69758	.04984	.73003	.05371	.76125	.05771
16	49	.66438	.04617	.69814	.04990	.73056	.05377	.76176	.05778
20	50	8.66496	0.04623	8.69869	0.04997	8.73109	0.05384	8.76227	0.05785
24	51	.66553	.04629	.69924	.05003	.73162	.05390	.76278	.05791
28	52	.66610	.04636	.69979	.05009	.73215	.05397	.76329	.05798
32	53	.66668	.04642	.70034	.05016	.73268	.05404	.76380	.05805
36	54	.66725	.04648	.70089	.05022	.73321	.05410	.76431	.05812
40	55	8.66782	0.04654	8.70144	0.05028	8.73374	0.05417	8.76481	0.05819
44	56	.66839	.04660	.70198	.05035	.73426	.05423	.76532	.05825
48	57	.66896	.04666	.70253	.05041	.73479	.05430	.76583	.05832
52	58	.66953	.04672	.70308	.05048	.73532	.05436	.76634	.05839
56	59	.67010	.04678	.70363	.05054	.73584	.05443	.76684	.05846
60	60	8.67067	0.04685	8.70418	0.05060	8.73637	0.05450	8.76735	0.05853

s	′	1h 52m Hav.	28° No.	1h 56m Hav.	29° No.	2h 0m Hav.	30° No.	2h 4m Hav.	31° No.
0	0	8.76735	0.05853	8.79720	0.06269	8.82599	0.06699	8.85380	0.07142
4	1	.76786	.05859	.79769	.06276	.82646	.06706	.85425	.07149
8	2	.76836	.05866	.79818	.06283	.82694	.06713	.85471	.07157
12	3	.76887	.05873	.79866	.06290	.82741	.06721	.85516	.07164
16	4	.76938	.05880	.79915	.06297	.82788	.06728	.85562	.07172
20	5	8.76988	0.05887	8.79964	0.06304	8.82835	0.06735	8.85607	0.07179
24	6	.77039	.05894	.80013	.06311	.82882	.06742	.85653	.07187
28	7	.77089	.05901	.80061	.06318	.82929	.06760	.85698	.07194
32	8	.77139	.06907	.80110	.06326	.82976	.06757	.85743	.07202
36	9	.77190	.05914	.80158	.06333	.83023	.06764	.85789	.07209
40	10	8.77240	0.05921	8.80207	0.06340	8.83069	0.06772	8.85834	0.07217
44	11	.77291	.05928	.80256	.06347	.83116	.06779	.85879	.07224
48	12	.77341	.05935	.80304	.06354	.83163	.06786	.85925	.07232
52	13	.77391	.06942	.80353	.06361	.83210	.06794	.85970	.07239
56	14	.77441	.05949	.80401	.06368	.83257	.06801	.86015	.07247
s	′	1h 53m	28°	1h 57m	29°	2h 1m	30°	2h 5m	31°
0	15	8.77492	0.05955	8.80449	0.06375	8.83303	0.06808	8.86060	0.07254
4	16	.77542	.05962	.80498	.06382	.83350	.06816	.86105	.07262
8	17	.77592	.05969	.80546	.06389	.83397	.06823	.86151	.07270
12	18	.77642	.05976	.80595	.06397	.83444	.06830	.86196	.07277
16	19	.77692	.05983	.80643	.06404	.83490	.06838	.86241	.07285
20	20	8.77742	0.05990	8.80691	0.06411	8.83537	0.06845	8.86286	0.07292
24	21	.77792	.05997	.80739	.06418	.83583	.06852	.86331	.07300
28	22	.77842	.06004	.80788	.06425	.83630	.06860	.86376	.07307
32	23	.77892	.06011	.80836	.06432	.83676	.06867	.86421	.07315
36	24	.77942	.06018	.80884	.06439	.83723	.06874	.86466	.07322
40	25	8.77992	0.06024	8.80932	0.06446	8.83769	0.06882	8.86511	0.07330
44	26	.78042	.06031	.80980	.06454	.83816	.06889	.86556	.07338
48	27	.78092	.06038	.81028	.06461	.83862	.06896	.86600	.07346
52	28	.78142	.06045	.81076	.06468	.83909	.06904	.86645	.07353
56	29	.78191	.06052	.81124	.06475	.83955	.06911	.86690	.07360
s	′	1h 54m	28°	1h 58m	29°	2h 2m	30°	2h 6m	31°
0	30	8.78241	0.06059	8.81172	0.06482	8.84002	0.06919	8.86735	0.07368
4	31	.78291	.06066	.81220	.06489	.84048	.06926	.86780	.07376
8	32	.78341	.06073	.81268	.06497	.84094	.06933	.86825	.07383
12	33	.78390	.06080	.81316	.06504	.84140	.06941	.86869	.07391
16	34	.78440	.06087	.81364	.06511	.84187	.06948	.86914	.07398
20	35	8.78490	0.06094	8.81412	0.06518	8.84233	0.06956	8.86959	0.07406
24	36	.78539	.06101	.81460	.06525	.84279	.06963	.87003	.07414
28	37	.78589	.06108	.81508	.06532	.84325	.06970	.87048	.07421
32	38	.78638	.06115	.81555	.06540	.84371	.06978	.87093	.07429
36	39	.78688	.06122	.81603	.06547	.84417	.06985	.87137	.07437
40	40	8.78737	0.06129	8.81651	0.06564	8.84464	0.06993	8.87182	0.07444
44	41	.78787	.06136	.81699	.06561	.84510	.07000	.87226	.07452
48	42	.78836	.06143	.81746	.06568	.84556	.07007	.87271	.07459
52	43	.78885	.06150	.81794	.06576	.84602	.07015	.87315	.07467
56	44	.78935	.06157	.81841	.06533	.84648	.07022	.87360	.07475
s	′	1h 55m	28°	1h 59m	29°	2h 3m	30°	2h 7m	31°
0	45	8.78984	0.06164	8.81889	0.06590	8.84694	0.07030	8.87404	0.07482
4	46	.79033	.06171	.81937	.06597	.84740	.07037	.87448	.07490
8	47	.79082	.06178	.81984	.06605	.84785	.07045	.87493	.07498
12	48	.79132	.06185	.82032	.06612	.84831	.07052	.87537	.07505
16	49	.79181	.06192	.82079	.06619	.84877	.07059	.87582	.07513
20	50	8.79230	0.06199	8.82126	0.06626	8.84923	0.07067	8.87626	0.07521
24	51	.79279	.06206	.82174	.06633	.84969	.07074	.87670	.07528
28	52	.79328	.06213	.82221	.06641	.85015	.07082	.87714	.07536
32	53	.79377	.06220	.82269	.06648	.85060	.07089	.87759	.07544
36	54	.79426	.06227	.82316	.06655	.85106	.07097	.87803	.07551
40	55	8.79475	0.06234	8.82363	0.06662	8.85152	0.07104	8.87847	0.07559
44	56	.79524	.06241	.82410	.06670	.85197	.07112	.87891	.07667
48	57	.79573	.06248	.82458	.06677	.85243	.07119	.87935	.07574
52	58	.79622	.06255	.82505	.06684	.85289	.07127	.87980	.07582
56	59	.79671	.06262	.82552	.06691	.85334	.07134	.88024	.07590
60	60	8.79720	0.06269	8.82599	0.06699	8.85380	0.07142	8.88068	0.07598

s	′	$2^h\ 8^m$ Hav.	32° No.	$2^h\ 12^m$ Hav.	33° No.	$2^h\ 16^m$ Hav.	34° No.	$2^h\ 20^m$ Hav.	35° No.
0	0	8.88068	0.07598	8.90668	0.08066	8.93187	0.08548	8.95628	0.09042
4	1	.88112	.07605	.90711	.08074	.93228	.08556	.95668	.09051
8	2	.88156	.07613	.90754	.08082	.93270	.08564	.95709	.09059
12	3	.88200	.07621	.90796	.08090	.93311	.08573	.95749	.09067
16	4	.88244	.07628	.90839	.08098	.93352	.08581	.95789	.09076
20	5	8.88288	0.07636	8.90881	0.08106	8.93393	0.08589	8.95828	0.09084
24	6	.88332	.07644	.90924	.08114	.93435	.08597	.95868	.09093
28	7	.88375	.07652	.90966	.08122	.93476	.08605	.95908	.09101
32	8	.88419	.07659	.91009	.08130	.93517	.08613	.95948	.09109
36	9	.88463	.07667	.91051	.08138	.93558	.08621	.95988	.09118
40	10	8.88507	0.07675	8.91094	0.08146	8.93599	0.08630	8.96028	0.09126
44	11	.88551	.07683	.91136	.08154	.93640	.08638	.96068	.09134
48	12	.88595	.07690	.91179	.08162	.93681	.08646	.96108	.09143
52	13	.88638	.07698	.91221	.08170	.93722	.08654	.96148	.09151
56	14	.88682	.07706	.91263	.08178	.93764	.08662	.96187	.09160
s	′	$2^h\ 9^m$	32°	$2^h\ 13^m$	33°	$2^h\ 17^m$	34°	$2^h\ 21^m$	35°
0	15	8.88726	0.07714	8.91306	0.08186	8.93805	0.08671	8.96227	0.09168
4	16	.88769	.07721	.91348	.08194	.93846	.08679	.96267	.09176
8	17	.88813	.07729	.91390	.08202	.93886	.08687	.96307	.09185
12	18	.88857	.07737	.91432	.08210	.93927	.08695	.96346	.09193
16	19	.88900	.07745	.91475	.08218	.93968	.08703	.96386	.09202
20	20	8.88944	0.07752	8.91517	0.08226	8.94009	0.08711	8.96426	0.09210
24	21	.88988	.07760	.91559	.08234	.94050	.08720	.96465	.09218
28	22	.89031	.07768	.91601	.08242	.94091	.08728	.96505	.09227
32	23	.89075	.07776	.91643	.08250	.94132	.08736	.96545	.09235
36	24	.89118	.07784	.91685	.08258	.94173	.08744	.96584	.09244
40	25	8.89162	0.07791	8.91728	0.08266	8.94213	0.08753	8.96624	0.09252
44	26	.89205	.07799	.91770	.08274	.94254	.08761	.96663	.09260
48	27	.89248	.07807	.91812	.08282	.94295	.08769	.96703	.09269
52	28	.89292	.07815	.91854	.08290	.94336	.08777	.96742	.09277
56	29	.89335	.07823	.91896	.08298	.94376	.08785	.96782	.09286
s	′	$2^h\ 10^m$	32°	$2^h\ 14^m$	33°	$2^h\ 18^m$	34°	$2^h\ 22^m$	35°
0	30	8.89379	0.07830	8.91938	0.08306	8.94417	0.08794	8.96821	0.09294
4	31	.89422	.07838	.91980	.08314	.94458	.08802	.96861	.09303
8	32	.89465	.07846	.92022	.08322	.94498	.08810	.96900	.09311
12	33	.89509	.07854	.92064	.08330	.94539	.08818	.96940	.09320
16	34	.89552	.07862	.92105	.08338	.94580	.08827	.96979	.09328
20	35	8.89595	0.07870	8.92147	0.08346	8.94620	0.08835	8.97018	0.09337
24	36	.89638	.07877	.92189	.08354	.94661	.08843	.97058	.09345
28	37	.89681	.07885	.92231	.08362	.94701	.08851	.97097	.09353
32	38	.89725	.07893	.92273	.08370	.94742	.08860	.97136	.09362
36	39	.89768	.07901	.92315	.08378	.94782	.08868	.97176	.09370
40	40	8.89811	0.07909	8.92356	0.08386	8.94823	0.08876	8.97215	0.09379
44	41	.89854	.07917	.92398	.08394	.94863	.08885	.97254	.09387
48	42	.89897	.07924	.92440	.08402	.94904	.08893	.97294	.09396
52	43	.89940	.07932	.92482	.08410	.94944	.08901	.97333	.09404
56	44	.89983	.07940	.92523	.08418	.94985	.08909	.97372	.09413
s	′	$2^h\ 11^m$	32°	$2^h\ 15^m$	33°	$2^h\ 19^m$	34°	$2^h\ 23^m$	35°
0	45	8.90026	0.07948	8.92565	0.08427	8.95025	0.08918	8.97411	0.09421
4	46	.90069	.07956	.92607	.08435	.95065	.08926	.97450	.09430
8	47	.90112	.07964	.92648	.08443	.95106	.08934	.97489	.09438
12	48	.90155	.07972	.92690	.08451	.95146	.08943	.97529	.09447
16	49	.90198	.07980	.92731	.08459	.95186	.08951	.97568	.09455
20	50	8.90241	0.07987	8.92773	0.08467	8.95227	0.08959	8.97607	0.09464
24	51	.90284	.07995	.92814	.08475	.95267	.08967	.97646	.09472
28	52	.90326	.08003	.92856	.08483	.95307	.08976	.97685	.09481
32	53	.90369	.08011	.92897	.08491	.95347	.08984	.97724	.09489
36	54	.90412	.08019	.92939	.08499	.95388	.08992	.97763	.09498
40	55	8.90455	0.08027	8.92980	0.08508	8.95428	0.09001	8.97802	0.09506
44	56	.90498	.08035	.93022	.08516	.95468	.09009	.97841	.09515
48	57	.90540	.08043	.93063	.08624	.95508	.09017	.97880	.09524
52	58	.90583	.08051	.93104	.08532	.95548	.09026	.97919	.09532
56	59	.90626	.08059	.93146	.08540	.95588	.09034	.97958	.09541
60	60	8.90668	0.08066	8.93187	0.08548	8.95628	0.09042	8.97997	0.09549

s	′	$2^h 24^m$	36°	$2^h 28^m$	37°	$2^h 32^m$	38°	$2^h 36^m$	39°
		Hav.	**No.**	**Hav.**	**No.**	**Hav.**	**No.**	**Hav.**	**No.**
0	0	8.97997	0.09549	9.00295	0.10068	9.02528	0.10599	9.04699	0.11143
4	1	.98035	.09558	.00333	.10077	.02565	.10608	.04735	.11152
8	2	.98074	.09566	.00371	.10086	.02602	.10617	.04770	.11161
12	3	.98113	.09575	.00408	.10095	.02638	.10626	.04806	.11170
16	4	.98152	.09583	.00446	.10103	.02675	.10635	.04842	.11179
20	5	8.98191	0.09592	9.00484	0.10112	9.02712	0.10644	9.04877	0.11189
24	6	.98229	.09601	.00522	.10121	.02748	.10653	.04913	.11198
28	7	.98268	.09609	.00559	.10130	.02785	.10662	.04948	.11207
32	8	.98307	.09618	.00597	.10138	.02821	.10671	.04984	.11216
36	9	.98346	.09626	.00634	.10147	.02858	.10680	.05019	.11225
40	10	8.98384	0.09635	9.00672	0.10156	9.02894	0.10689	9.05055	0.11234
44	11	.98423	.09643	.00710	.10165	.02931	.10698	.05090	.11244
48	12	.98462	.09652	.00747	.10174	.02967	.10707	.05126	.11253
52	13	.98500	.09661	.00785	.10182	.03004	.10716	.05161	.11262
56	14	.98539	.09669	.00822	.10191	.03040	.10725	.05197	.11271
s	′	$2^h 25^m$	36°	$2^h 29^m$	37°	$2^h 33^m$	38°	$2^h 37^m$	39°
0	15	8.98578	0.09678	9.00860	0.10200	9.03077	0.10734	9.05232	0.11280
4	16	.98616	.09686	.00897	.10209	.03113	.10743	.05268	.11290
8	17	.98655	.09695	.00935	.10218	.03150	.10752	.05303	.11299
12	18	.98693	.09704	.00972	.10226	.03186	.10761	.05339	.11308
16	19	.98732	.09712	.01009	.10235	.03222	.10770	.05374	.11317
20	20	8.98770	0.09721	9.01047	0.10244	9.03259	0.10779	9.05409	0.11326
24	21	.98809	.09729	.01084	.10253	.03295	.10788	.05445	.11336
28	22	.98847	.09738	.01122	.10262	.03331	.10797	.05480	.11345
32	23	.98886	.09747	.01159	.10270	.03368	.10806	.05515	.11354
36	24	.98924	.09755	.01196	.10279	.03404	.10815	.05551	.11363
40	25	8.98963	0.09764	9.01234	0.10288	9.03440	0.10824	9.05586	0.11373
44	26	.99001	.09773	.01271	.10297	.03476	.10833	.05621	.11382
48	27	.99039	.09781	.01308	.10306	.03513	.10842	.05656	.11391
52	28	.99078	.09790	.01345	.10315	.03549	.10851	.05692	.11400
56	29	.99116	.09799	.01383	.10323	.03585	.10861	.05727	.11410
s	′	$2^h 26^m$	36°	$2^h 30^m$	37°	$2^h 34^m$	38°	$2^h 38^m$	39°
0	30	8.99154	0.09807	9.01420	0.10332	9.03621	0.10870	9.05762	0.11419
4	31	.99193	.09816	.01457	.10341	.03657	.10879	.05797	.11428
8	32	.99231	.09824	.01494	.10350	.03694	.10888	.05832	.11437
12	33	.99269	.09833	.01531	.10359	.03730	.10897	.05867	.11447
16	34	.99307	.09842	.01569	.10368	.03766	.10906	.05903	.11456
20	35	8.99346	0.09850	9.01606	0.10377	9.03802	0.10915	9.05938	0.11465
24	36	.99384	.09859	.01643	.10386	.03838	.10924	.05973	.11474
28	37	.99422	.09868	.01680	.10394	.03874	.10933	.06008	.11484
32	38	.99460	.09876	.01717	.10403	.03910	.10942	.06043	.11493
36	39	.99498	.09885	.01754	.10412	.03946	.10951	.06078	.11502
40	40	8.99536	0.09894	9.01791	0.10421	9.03982	0.10960	9.06113	0.11511
44	41	.99575	.09903	.01828	.10430	.04018	.10969	.06148	.11521
48	42	.99613	.09911	.01865	.10439	.04054	.10978	.06183	.11530
52	43	.99651	.09920	.01902	.10448	.04090	.10988	.06218	.11539
56	44	.99689	.09929	.01939	.10457	.04126	.10997	.06253	.11549
s	′	$2^h 27^m$	36°	$2^h 31^m$	37°	$2^h 35^m$	38°	$2^h 39^m$	39°
0	45	8.99727	0.09937	9.01976	0.10466	9.04162	0.11006	9.06288	0.11558
4	46	.99765	.09946	.02013	.10474	.04198	.11015	.06323	.11567
8	47	.99803	.09955	.02050	.10483	.04234	.11024	.06358	.11577
12	48	.99841	.09963	.02087	.10492	.04270	.11033	.06393	.11586
16	49	.99879	.09972	.02124	.10501	.04306	.11042	.06428	.11595
20	50	8.99917	0.09981	9.02161	0.10510	9.04341	0.11051	9.06462	0.11604
24	51	.99955	.09990	.02197	.10519	.04377	.11060	.06497	.11614
28	52	.99993	.09998	.02234	.10528	.04413	.11070	.06532	.11623
32	53	9.00031	.10007	.02271	.10537	.04449	.11079	.06567	.11632
36	54	.00068	.10016	.02308	.10546	.04485	.11088	.06602	.11642
40	55	9.00106	0.10025	9.02345	0.10555	9.04520	0.11097	9.06637	0.11651
44	56	.00144	.10033	.02381	.10564	.04556	.11106	.06671	.11660
48	57	.00182	.10042	.02418	.10573	.04592	.11115	.06706	.11670
52	58	.00220	.10051	.02455	.10582	.04628	.11124	.06741	.11679
56	59	.00258	.10059	.02492	.10591	.04663	.11134	.06776	.11688
60	60	9.00295	0.10068	9.02528	0.10599	9.04699	0.11143	9.06810	0.11698

s	′	$2^h\,40^m$ 40° Hav.	No.	$2^h\,44^m$ 41° Hav.	No.	$2^h\,48^m$ 42° Hav.	No.	$2^h\,52^m$ 43° Hav.	No.
0	0	9.06810	**0.11698**	9.08865	**0.12265**	9.10866	**0.12843**	9.12815	**0.13432**
4	1	.06845	**.11707**	.08899	**.12274**	.10899	**.12852**	.12847	**.13442**
8	2	.06880	**.11716**	.08933	**.12284**	.10932	**.12862**	.12879	**.13452**
12	3	.06914	**.11726**	.08966	**.12293**	.10965	**.12872**	.12911	**.13462**
16	4	.06949	**.11735**	.09000	**.12303**	.10997	**.12882**	.12943	**.13472**
20	5	9.06984	**0.11745**	9.09034	**0.12312**	9.11030	**0.12891**	9.12975	**0.13482**
24	6	.07018	**.11754**	.09068	**.12322**	.11063	**.12901**	.13007	**.13492**
28	7	.07053	**.11763**	.09101	**.12331**	.11096	**.12911**	.13039	**.13502**
32	8	.07088	**.11773**	.09135	**.12341**	.11129	**.12921**	.13071	**.13512**
36	9	.07122	**.11782**	.09169	**.12351**	.11161	**.12930**	.13103	**.13522**
40	10	9.07157	**0.11791**	9.09202	**0.12360**	9.11194	**0.12940**	9.13135	**0.13532**
44	11	.07191	**.11801**	.09236	**.12370**	.11227	**.12950**	.13167	**.13542**
48	12	.07226	**.11810**	.09269	**.12379**	.11260	**.12960**	.13199	**.13552**
52	13	.07260	**.11820**	.09303	**.12389**	.11292	**.12970**	.13231	**.13562**
56	14	.07295	**.11829**	.09337	**.12398**	.11325	**.12979**	.13263	**.13571**
s	′	$2^h\,41^m$	40°	$2^h\,45^m$	41°	$2^h\,49^m$	42°	$2^h\,53^m$	43°
0	15	9.07329	**0.11838**	9.09370	**0.12408**	9.11358	**0.12989**	9.13295	**0.13581**
4	16	.07364	**.11848**	.09404	**.12418**	.11391	**.12999**	.13326	**.13691**
8	17	.07398	**.11857**	.09437	**.12427**	.11423	**.13009**	.13358	**.13601**
12	18	.07433	**.11867**	.09471	**.12437**	.11456	**.13018**	.13390	**.13611**
16	19	.07467	**.11876**	.09504	**.12446**	.11489	**.13028**	.13422	**.13621**
20	20	9.07501	**0.11885**	9.09538	**0.12466**	9.11521	**0.13038**	9.13454	**0.13631**
24	21	.07536	**.11896**	.09571	**.12466**	.11554	**.13048**	.13486	**.13641**
28	22	.07570	**.11904**	.09605	**.12475**	.11586	**.13068**	.13517	**.13651**
32	23	.07605	**.11914**	.09638	**.12485**	.11619	**.13067**	.13549	**.13661**
36	24	.07639	**.11923**	.09672	**.12494**	.11652	**.13077**	.13581	**.13671**
40	25	9.07673	**0.11933**	9.09705	**0.12504**	9.11684	**0.13087**	9.13613	**0.13681**
44	26	.07708	**.11942**	.09739	**.12514**	.11717	**.13097**	.13644	**.13691**
48	27	.07742	**.11951**	.09772	**.12523**	.11749	**.13107**	.13676	**.13701**
52	28	.07776	**.11961**	.09805	**.12633**	.11782	**.13116**	.13708	**.13711**
56	29	.07810	**.11970**	.09839	**.12543**	.11814	**.13126**	.13739	**.13721**
s	′	$2^h\,42^m$	40°	$2^h\,46^m$	41°	$2^h\,50^m$	42°	$2^h\,54^m$	43°
0	30	9.07845	**0.11980**	9.09872	**0.12562**	9.11847	**0.13136**	9.13771	**0.13731**
4	31	.07879	**.11989**	.09905	**.12562**	.11879	**.13146**	.13803	**.13741**
8	32	.07913	**.11999**	.09939	**.12672**	.11912	**.13156**	.13834	**.13751**
12	33	.07947	**.12008**	.09972	**.12681**	.11944	**.13166**	.13866	**.13761**
16	34	.07981	**.12018**	.10005	**.12591**	.11977	**.13175**	.13898	**.13771**
20	35	9.08016	**0.12027**	9.10039	**0.12600**	9.12009	**0.13185**	9.13929	**0.13781**
24	36	.08050	**.12036**	.10072	**.12610**	.12041	**.13196**	.13961	**.13791**
28	37	.08084	**.12046**	.10105	**.12620**	.12074	**.13206**	.13992	**.13801**
32	38	.08118	**.12055**	.10138	**.12629**	.12106	**.13215**	.14024	**.13811**
36	39	.08152	**.12065**	.10172	**.12639**	.12139	**.13226**	.14056	**.13822**
40	40	9.08186	**0.12074**	9.10205	**0.12649**	9.12171	**0.13235**	9.14087	**0.13832**
44	41	.08220	**.12084**	.10238	**.12658**	.12203	**.13244**	.14119	**.13842**
48	42	.08254	**.12093**	.10271	**.12668**	.12236	**.13264**	.14150	**.13852**
52	43	.08288	**.12103**	.10304	**.12678**	.12268	**.13264**	.14182	**.13862**
56	44	.08323	**.12112**	.10337	**.12687**	.12300	**.13274**	.14213	**.13872**
s	′	$2^h\,43^m$	40°	$2^h\,47^m$	41°	$2^h\,51^m$	42°	$2^h\,55^m$	43°
0	45	9.08357	**0.12122**	9.10371	**0.12697**	9.12332	**0.13284**	9.14245	**0.13882**
4	46	.08391	**.12131**	.10404	**.12707**	.12365	**.13294**	.14276	**.13892**
8	47	.08425	**.12141**	.10437	**.12717**	.12397	**.13304**	.14307	**.13902**
12	48	.08459	**.12160**	.10470	**.12726**	.12429	**.13314**	.14339	**.13912**
16	49	.08492	**.12160**	.10503	**.12736**	.12461	**.13323**	.14370	**.13922**
20	50	9.08526	**0.12169**	9.10536	**0.12746**	9.12494	**0.13333**	9.14402	**0.13932**
24	61	.08560	**.12179**	.10569	**.12756**	.12526	**.13343**	.14433	**.13942**
28	52	.08594	**.12188**	.10602	**.12765**	.12558	**.13363**	.14465	**.13962**
32	53	.08628	**.12198**	.10635	**.12775**	.12590	**.13363**	.14496	**.13962**
36	54	.08662	**.12207**	.10668	**.12784**	.12622	**.13373**	.14527	**.13972**
40	55	9.08696	**0.12217**	9.10701	**0.12794**	9.12655	**0.13383**	9.14559	**0.13983**
44	56	.08730	**.12226**	.10734	**.12804**	.12687	**.13393**	.14590	**.13993**
48	57	.08764	**.12236**	.10767	**.12814**	.12719	**.13403**	.14621	**.14003**
52	68	.08797	**.12245**	.10800	**.12823**	.12751	**.13412**	.14653	**.14013**
56	59	.08831	**.12255**	.10833	**.12833**	.12783	**.13422**	.14684	**.14023**
60	60	9.08865	**0.12266**	9.10866	**0.12843**	9.12815	**0.13432**	9.14715	**0.14033**

s	′	$2^h\ 56^m$	44°	$3^h\ 0^m$	45°	$3^h\ 4^m$	46°	$3^h\ 8^m$	47°
		Hav.	No.	Hav.	No.	Hav.	No.	Hav.	No.
0	**0**	9.14715	**0.14033**	9.16568	**0.14645**	9.18376	**0.15267**	9.20140	**0.15900**
4	**1**	.14746	**.14043**	.16598	**.14655**	.18405	**.15278**	.20169	**.15911**
8	**2**	.14778	**.14053**	.16629	**.14665**	.18435	**.15288**	.20198	**.15921**
12	**3**	.14809	**.14063**	.16659	**.14676**	.18465	**.15298**	.20227	**.15932**
16	**4**	.14840	**.14073**	.16690	**.14686**	.18495	**.15309**	.20256	**.15943**
20	**5**	9.14871	**0.14084**	9.16720	**0.14696**	9.18524	**0.15319**	9.20285	**0.15953**
24	**6**	.14902	**.14094**	.16751	**.14706**	.18554	**.15330**	.20314	**.15964**
28	**7**	.14934	**.14104**	.16781	**.14717**	.18584	**.15340**	.20343	**.15975**
32	**8**	.14965	**.14114**	.16812	**.14727**	.18613	**.15351**	.20372	**.15985**
36	**9**	.14996	**.14124**	.16842	**.14737**	.18643	**.15361**	.20401	**.15996**
40	**10**	9.15027	**0.14134**	9.16872	**0.14748**	9.18673	**0.15372**	9.20430	**0.16007**
44	**11**	.15058	**.14144**	.16903	**.14758**	.18702	**.15382**	.20459	**.16017**
48	**12**	.15089	**.14154**	.16933	**.14768**	.18732	**.15393**	.20488	**.16028**
52	**13**	.15120	**.14165**	.16963	**.14779**	.18762	**.15403**	.20517	**.16039**
56	**14**	.15152	**.14175**	.16994	**.14789**	.18791	**.15414**	.20546	**.16049**
s	′	$2^h\ 57^m$	44°	$3^h\ 1^m$	45°	$3^h\ 5^m$	46°	$3^h\ 9^m$	47°
0	**15**	9.15183	**0.14185**	9.17024	**0.14799**	9.18821	**0.15424**	9.20574	**0.16060**
4	**16**	.15214	**.14195**	.17054	**.14810**	.18850	**.15435**	.20603	**.16071**
8	**17**	.15245	**.14205**	.17085	**.14820**	.18880	**.15445**	.20632	**.16081**
12	**18**	.15276	**.14215**	.17115	**.14830**	.18909	**.15456**	.20661	**.16092**
16	**19**	.15307	**.14226**	.17145	**.14841**	.18939	**.15466**	.20690	**.16103**
20	**20**	9.15338	**0.14236**	9.17175	**0.14851**	9.18968	**0.15477**	9.20719	**0.16113**
24	**21**	.15369	**.14246**	.17206	**.14861**	.18998	**.15487**	.20748	**.16124**
28	**22**	.15400	**.14256**	.17236	**.14872**	.19027	**.15498**	.20776	**.16135**
32	**23**	.15431	**.14266**	.17266	**.14882**	.19057	**.15509**	.20805	**.16146**
36	**24**	.15462	**.14276**	.17296	**.14892**	.19086	**.15519**	.20834	**.16156**
40	**25**	9.15493	**0.14287**	9.17327	**0.14903**	9.19116	**0.15530**	9.20863	**0.16167**
44	**26**	.15524	**.14297**	.17357	**.14913**	.19145	**.15540**	.20891	**.16178**
48	**27**	.15555	**.14307**	.17387	**.14923**	.19175	**.15551**	.20920	**.16188**
52	**28**	.15585	**.14317**	.17417	**.14934**	.19204	**.15561**	.20949	**.16199**
56	**29**	.15616	**.14327**	.17447	**.14944**	.19234	**.15572**	.20978	**.16210**
s	′	$2^h\ 58^m$	44°	$3^h\ 2^m$	45°	$3^h\ 6^m$	46°	$3^h\ 10^m$	47°
0	**30**	9.15647	**0.14337**	9.17477	**0.14955**	9.19263	**0.15582**	9.21006	**0.16220**
4	**31**	.15678	**.14348**	.17507	**.14965**	.19292	**.15593**	.21035	**.16231**
8	**32**	.15709	**.14358**	.17538	**.14975**	.19322	**.15603**	.21064	**.16242**
12	**33**	.15740	**.14368**	.17568	**.14986**	.19351	**.15614**	.21092	**.16253**
16	**34**	.15771	**.14378**	.17598	**.14996**	.19381	**.15625**	.21121	**.16263**
20	**35**	9.15802	**0.14388**	9.17628	**0.15006**	9.19410	**0.15635**	9.21150	**0.16274**
24	**36**	.15832	**.14399**	.17658	**.15017**	.19439	**.15646**	.21178	**.16285**
28	**37**	.15863	**.14409**	.17688	**.15027**	.19469	**.15656**	.21207	**.16296**
32	**38**	.15894	**.14419**	.17718	**.15038**	.19498	**.15667**	.21236	**.16306**
36	**39**	.15925	**.14429**	.17748	**.15048**	.19527	**.15677**	.21264	**.16317**
40	**40**	9.15955	**0.14440**	9.17778	**0.15058**	9.19557	**0.15688**	9.21293	**0.16328**
44	**41**	.15986	**.14450**	.17808	**.15069**	.19586	**.15699**	.21322	**.16339**
48	**42**	.16017	**.14460**	.17838	**.15079**	.19615	**.15709**	.21350	**.16349**
52	**43**	.16048	**.14470**	.17868	**.15090**	.19644	**.15720**	.21379	**.16360**
56	**44**	.16078	**.14480**	.17898	**.15100**	.19674	**.15730**	.21407	**.16371**
s	′	$2^h\ 59^m$	44°	$3^h\ 3^m$	45°	$3^h\ 7^m$	46°	$3^h\ 11^m$	47°
0	**45**	9.16109	**0.14491**	9.17928	**0.15110**	9.19703	**0.15741**	9.21436	**0.16382**
4	**46**	.16140	**.14501**	.17958	**.15121**	.19732	**.15751**	.21464	**.16392**
8	**47**	.16170	**.14511**	.17988	**.15131**	.19761	**.15762**	.21493	**.16403**
12	**48**	.16201	**.14521**	.18018	**.15142**	.19790	**.15773**	.21521	**.16414**
16	**49**	.16232	**.14532**	.18048	**.15152**	.19820	**.15783**	.21550	**.16425**
20	**50**	9.16262	**0.14542**	9.18077	**0.15163**	9.19849	**0.15794**	9.21578	**0.16436**
24	**51**	.16293	**.14552**	.18107	**.15173**	.19878	**.15804**	.21607	**.16446**
28	**52**	.16324	**.14562**	.18137	**.15183**	.19907	**.15815**	.21635	**.16457**
32	**53**	.16354	**.14573**	.18167	**.15194**	.19936	**.15826**	.21664	**.16468**
36	**54**	.16385	**.14583**	.18197	**.15204**	.19965	**.15836**	.21692	**.16479**
40	**55**	9.16415	**0.14593**	9.18227	**0.15215**	9.19995	**0.15847**	9.21721	**0.16489**
44	**56**	.16446	**.14604**	.18256	**.15225**	.20024	**.15858**	.21749	**.16500**
48	**57**	.16476	**.14614**	.18286	**.15236**	.20053	**.15868**	.21778	**.16511**
52	**58**	.16507	**.14624**	.18316	**.15246**	.20082	**.15879**	.21806	**.16522**
56	**59**	.16537	**.14634**	.18346	**.15257**	.20111	**.15889**	.21834	**.16533**
60	**60**	9.16568	**0.14645**	9.18376	**0.15267**	9.20140	**0.15900**	9.21863	**0.16543**

s	′	3h 12m Hav.	48° No.	3h 16m Hav.	49° No.	3h 20m Hav.	50° No.	3h 24m Hav.	51° No.
0	0	9.21863	0.16543	9.23545	0.17197	9.25190	0.17861	9.26797	0.18534
4	1	.21891	.16554	.23573	.17208	.25217	.17872	.26823	.18545
8	2	.21919	.16565	.23601	.17219	.25244	.17883	.26850	.18557
12	3	.21948	.16576	.23629	.17230	.25271	.17894	.26876	.18568
16	4	.21976	.16587	.23656	.17241	.25298	.17905	.26903	.18579
20	5	9.22004	0.16598	9.23684	0.17252	9.25325	0.17916	9.26929	0.18591
24	6	.22033	.16608	.23712	.17263	.25352	.17928	.26956	.18602
28	7	.22061	.16619	.23739	.17274	.25379	.17939	.26982	.18613
32	8	.22089	.16630	.23767	.17285	.25406	.17950	.27008	.18624
36	9	.22118	.16641	.23794	.17296	.25433	.17961	.27035	.18636
40	10	9.22146	0.16652	9.23822	0.17307	9.25460	0.17972	9.27061	0.18647
44	11	.22174	.16663	.23850	.17318	.25487	.17983	.27088	.18658
48	12	.22202	.16673	.23877	.17329	.25514	.17995	.27114	.18670
52	13	.22231	.16684	.23905	.17340	.25541	.18006	.27140	.18681
56	14	.22259	.16695	.23932	.17351	.25568	.18017	.27167	.18692
s	′	3h 13m	48°	3h 17m	49°	3h 21m	50°	3h 25m	51°
0	15	9.22287	0.16706	9.23960	0.17362	9.25595	0.18028	9.27193	0.18704
4	16	.22315	.16717	.23988	.17373	.25622	.18039	.27219	.18715
8	17	.22343	.16728	.24015	.17384	.25649	.18050	.27246	.18727
12	18	.22372	.16738	.24043	.17395	.25676	.18062	.27272	.18738
16	19	.22400	.16749	.24070	.17406	.25703	.18073	.27298	.18749
20	20	9.22428	0.16760	9.24098	0.17417	9.25729	0.18084	9.27325	0.18761
24	21	.22456	.16771	.24125	.17428	.25756	.18095	.27351	.18772
28	22	.22484	.16782	.24153	.17439	.25783	.18106	.27377	.18783
32	23	.22512	.16793	.24180	.17450	.25810	.18118	.27403	.18795
36	24	.22540	.16804	.24208	.17461	.25837	.18129	.27430	.18806
40	25	9.22569	0.16815	9.24235	0.17472	9.25864	0.18140	9.27456	0.18817
44	26	.22597	.16825	.24263	.17483	.25891	.18151	.27482	.18829
48	27	.22625	.16836	.24290	.17494	.25917	.18162	.27508	.18840
52	28	.22653	.16847	.24317	.17505	.25944	.18174	.27535	.18852
56	29	.22681	.16858	.24345	.17517	.25971	.18185	.27561	.18863
s	′	3h 14m	48°	3h 18m	49°	3h 22m	50°	3h 26m	51°
0	30	9.22709	0.16869	9.24372	0.17528	9.25998	0.18196	9.27587	0.18874
4	31	.22737	.16880	.24400	.17539	.26025	.18207	.27613	.18886
8	32	.22765	.16891	.24427	.17550	.26051	.18219	.27639	.18897
12	33	.22793	.16902	.24454	.17561	.26078	.18230	.27666	.18908
16	34	.22821	.16913	.24482	.17572	.26105	.18241	.27692	.18920
20	35	9.22849	0.16924	9.24509	0.17583	9.26132	0.18252	9.27718	0.18931
24	36	.22877	.16934	.24536	.17594	.26158	.18263	.27744	.18943
28	37	.22905	.16945	.24564	.17605	.26185	.18275	.27770	.18954
32	38	.22933	.16956	.24591	.17616	.26212	.18286	.27796	.18965
36	39	.22961	.16967	.24618	.17627	.26238	.18297	.27822	.18977
40	40	9.22989	0.16978	9.24646	0.17638	9.26265	0.18308	9.27848	0.18988
44	41	.23017	.16989	.24673	.17649	.26292	.18320	.27875	.19000
48	42	.23045	.17000	.24700	.17661	.26319	.18331	.27901	.19011
52	43	.23073	.17011	.24728	.17672	.26345	.18342	.27927	.19022
56	44	.23100	.17022	.24755	.17683	.26372	.18353	.27953	.19034
s	′	3h 15m	48°	3h 19m	49°	3h 23m	50°	3h 27m	51°
0	45	9.23128	0.17033	9.24782	0.17694	9.26398	0.18365	9.27979	0.19045
4	46	.23156	.17044	.24809	.17705	.26425	.18376	.28005	.19057
8	47	.23184	.17055	.24837	.17716	.26452	.18387	.28031	.19068
12	48	.23212	.17066	.24864	.17727	.26478	.18399	.28057	.19080
16	49	.23240	.17076	.24891	.17738	.26505	.18410	.28083	.19091
20	50	9.23268	0.17087	9.24918	0.17749	9.26532	0.18421	9.28109	0.19102
24	51	.23295	.17098	.24945	.17760	.26558	.18432	.28135	.19114
28	52	.23323	.17109	.24973	.17772	.26585	.18444	.28161	.19125
32	53	.23351	.17120	.25000	.17783	.26611	.18455	.28187	.19137
36	54	.23379	.17131	.25027	.17794	.26638	.18466	.28213	.19148
40	55	9.23407	0.17142	9.25054	0.17805	9.26664	0.18478	9.28239	0.19160
44	56	.23434	.17153	.25081	.17816	.26691	.18489	.28265	.19171
48	57	.23462	.17164	.25108	.17827	.26717	.18500	.28291	.19183
52	58	.23490	.17175	.25135	.17838	.26744	.18511	.28317	.19194
56	59	.23518	.17186	.25163	.17849	.26770	.18523	.28342	.19205
60	60	9.23545	0.17197	9.25190	0.17861	9.26797	0.18534	9.28368	0.19217

s	′	$3^h\ 28^m$	52°	$3^h\ 32^m$	53°	$3^h\ 36^m$	54°	$3^h\ 40^m$	55°
		Hav.	**No.**	**Hav.**	**No.**	**Hav.**	**No.**	**Hav.**	**No.**
0	0	9.28368	0.19217	9.29906	0.19909	9.31409	0.20611	9.32881	0.21321
4	1	.28394	.19228	.29931	.19921	.31434	.20623	.32905	.21333
8	2	.28420	.19240	.29956	.19932	.31459	.20634	.32930	.21345
12	3	.28446	.19251	.29981	.19944	.31484	.20646	.32954	.21357
16	4	.28472	.19263	.30007	.19956	.31508	.20658	.32978	.21369
20	5	9.28498	0.19274	9.30032	0.19967	9.31533	0.20670	9.33002	0.21381
24	6	.28524	.19286	.30057	.19979	.31558	.20681	.33027	.21393
28	7	.28549	.19297	.30083	.19991	.31583	.20693	.33051	.21405
32	8	.28575	.19309	.30108	.20002	.31607	.20705	.33075	.21417
36	9	.28601	.19320	.30133	.20014	.31632	.20717	.33099	.21429
40	10	9.28627	0.19332	9.30158	0,20026	9.31657	0.20729	9.33123	0.21440
44	11	.28653	.19343	.30184	.20037	.31682	.20740	.33148	.21452
48	12	.28679	.19355	.30209	.20049	.31706	.20752	.33172	.21464
52	13	.28704	.19366	.30234	.20060	.31731	.20764	.33196	.21476
56	14	.28730	.19378	.30259	.20072	.31756	.20776	.33220	.21488
s	′	$3^h\ 29^m$	52°	$3^h\ 33^m$	53°	$3^h\ 37^m$	54°	$3^h\ 41^m$	55°
0	15	9.28756	0.19389	9.30285	0.20084	9.31780	0.20788	9.33244	0.21500
4	16	.28782	.19401	.30310	.20095	.31805	.20799	.33268	.21512
8	17	.28807	.19412	.30335	.20107	.31830	.20811	.33292	.21524
12	18	.28833	.19424	.30360	.20119	.31854	.20823	.33317	.21536
16	19	.28859	.19435	.30385	.20130	.31879	.20835	.33341	.21548
20	20	9.28885	0.19447	9.30410	0.20142	9.31903	0.20847	9.33365	0.21560
24	21	.28910	.19458	.30436	.20154	.31928	.20858	.33389	.21572
28	22	.28936	.19470	.30461	.20165	.31953	.20870	.33413	.21584
32	23	.28962	.19481	.30486	.20177	.31977	.20882	.33437	.21596
36	24	.28987	.19493	.30511	.20189	.32002	.20894	.33461	.21608
40	25	9.29013	0.19504	9.30536	0.20200	9.32026	0.20906	9.33485	0.21620
44	26	.29039	.19516	.30561	.20212	.32051	.20918	.33509	.21632
48	27	.29064	.19527	.30586	.20224	.32076	.20929	.33533	.21644
52	28	.29090	.19539	.30611	.20235	.32100	.20941	.33557	.21656
56	29	.29116	.19550	.30636	.20247	.32125	.20953	.33581	.21668
s	′	$3^h\ 30^m$	52°	$3^h\ 34^m$	53°	$3^h\ 38^m$	54°	$3^h\ 42^m$	55°
0	30	9.29141	0.19562	9.30662	0.20259	9.32149	0.20965	9.33605	0.21680
4	31	.29167	.19573	.30687	.20271	.32174	.20977	.33629	.21692
8	32	.29192	.19585	.30712	.20282	.32198	.20989	.33653	.21704
12	33	.29218	.19597	.30737	.20294	.32223	.21000	.33677	.21716
16	34	.29244	.19608	.30762	.20306	.32247	.21012	.33701	.21728
20	35	9.29269	0.19620	9.30787	0.20317	9.32272	0.21024	9.33725	0.21740
24	36	.29295	.19631	.30812	.20329	.32296	.21036	.33749	.21752
28	37	.29320	.19643	.30837	.20341	.32321	.21048	.33773	.21764
32	38	.29346	.19654	.30862	.20352	.32345	.21060	.33797	.21776
36	39	.29371	.19666	.30887	.20364	.32370	.21072	.33821	.21788
40	40	9.29397	0.19677	9.30912	0.20376	9.32394	0.21083	9.33845	0.21800
44	41	.29422	.19689	.30937	.20388	.32418	.21095	.33869	.21812
48	42	.29448	.19701	.30962	.20399	.32443	.21107	.33893	.21824
52	43	.29473	.19712	.30987	.20411	.32467	.21119	.33917	.21836
56	44	.29499	.19724	.31012	.20423	.32492	.21131	.33941	.21848
s	′	$3^h\ 31^m$	52°	$3^h\ 35^m$	53°	$3^h\ 39^m$	54°	$3^h\ 43^m$	55°
0	45	9.29524	0.19735	9.31036	0.20435	9.32516	0.21143	9.33965	0.21860
4	46	.29550	.19747	.31061	.20446	.32541	.21155	.33988	.21872
8	47	.29575	.19758	.31086	.20458	.32565	.21167	.34012	.21884
12	48	.29601	.19770	.31111	.20470	.32589	.21178	.34036	.21896
16	49	.29626	.19782	.31136	.20481	.32614	.21190	.34060	.21908
20	50	9.29652	0.19793	9.31161	0.20493	9.32638	0.21202	9.34084	0.21920
24	51	.29677	.19805	.31186	.20505	.32662	.21214	.34108	.21932
28	52	.29703	.19816	.31211	.20517	.32687	.21226	.34132	.21944
32	53	.29728	.19828	.31236	.20528	.32711	.21238	.34155	.21956
36	54	.29753	.19840	.31260	.20540	.32735	.21250	.34179	.21968
40	55	9.29779	0.19851	9.31285	0.20552	9.32760	0.21262	9.34203	0.21980
44	56	.29804	.19863	.31310	.20564	.32784	.21274	.34227	.21992
48	57	.29829	.19874	.31335	.20575	.32808	.21285	.34251	.22004
52	58	.29855	.19886	.31360	.20587	.32833	.21297	.34274	.22016
56	59	.29880	.19898	.31385	.20599	.32857	.21309	.34298	.22028
60	60	9.29906	0.19909	9.31409	0.20611	9.32881	0.21321	9.34322	0.22040

s	′	$3^h\ 44^m$	56°	$3^h\ 48^m$	57°	$3^h\ 52^m$	58°	$3^h\ 56^m$	59°
		Hav.	**No.**	**Hav.**	**No.**	**Hav.**	**No.**	**Hav.**	**No.**
0	**0**	9.34322	**0.22040**	9.35733	**0.22768**	9.37114	**0.23504**	9.38468	**0.24248**
4	**1**	.34346	**.22052**	.35756	**.22780**	.37137	**.23516**	.38490	**.24261**
8	**2**	.34369	**.22064**	.35779	**.22792**	.37160	**.23629**	.38512	**.24273**
12	**3**	.34393	**.22077**	.35802	**.22805**	.37183	**.23541**	.38535	**.24286**
16	**4**	.34417	**.22089**	.35826	**.22817**	.37205	**.23553**	.38557	**.24298**
20	**5**	9.34441	**0.22101**	9.35849	**0.22829**	9.37228	**0.23566**	9.38579	**0.24310**
24	**6**	.34464	**.22113**	.35872	**.22841**	.37251	**.23578**	.38602	**.24323**
28	**7**	.34488	**.22125**	.35895	**.22853**	.37274	**.23590**	.38624	**.24336**
32	**8**	.34512	**.22137**	.35918	**.22866**	.37296	**.23603**	.38646	**.24348**
36	**9**	.34535	**.22149**	.35942	**.22878**	.37319	**.23615**	.38668	**.24360**
40	**10**	9.34559	**0.22161**	9.35965	**0.22890**	9.37342	**0.23627**	9.38691	**0.24373**
44	**11**	.34583	**.22173**	.35988	**.22902**	.37364	**.23640**	.38713	**.24385**
48	**12**	.34606	**.22185**	.36011	**.22915**	.37387	**.23652**	.38735	**.24398**
52	**13**	.34630	**.22197**	.36034	**.22927**	.37410	**.23665**	.38757	**.24410**
56	**14**	.34654	**.22209**	.36058	**.22939**	.37433	**.23677**	.38780	**.24423**
s	′	$3^h\ 45^m$	56°	$3^h\ 49^m$	57°	$3^h\ 53^m$	58°	$3^h\ 57^m$	69°
0	**15**	9.34677	**0.22221**	9.36081	**0.22951**	9.37455	**0.23689**	9.38802	**0.24435**
4	**16**	.34701	**.22234**	.36104	**.22964**	.37478	**.23702**	.38824	**.24448**
8	**17**	.34725	**.22246**	.36127	**.22976**	.37501	**.23714**	.38846	**.24460**
12	**18**	.34748	**.22258**	.36150	**.22988**	.37523	**.23726**	.38868	**.24473**
16	**19**	.34772	**.22270**	.36173	**.23000**	.37546	**.23739**	.38891	**.24485**
20	**20**	9.34795	**0.22282**	9.36196	**0.23012**	9.37569	**0.23751**	9.38913	**0.24498**
24	**21**	.34819	**.22294**	.36219	**.23025**	.37591	**.23764**	.38935	**.24510**
28	**22**	.34843	**.22306**	.36243	**.23037**	.37614	**.23776**	.38957	**.24523**
32	**23**	.34866	**.22318**	.36266	**.23049**	.37636	**.23788**	.38979	**.24535**
36	**24**	.34890	**.22330**	.36289	**.23061**	.37659	**.23801**	.39002	**.24548**
40	**25**	9.34913	**0.22343**	9.36312	**0.23074**	9.37682	**0.23813**	9.39024	**0.24560**
44	**26**	.34937	**.22355**	.36335	**.23086**	.37704	**.23825**	.39046	**.24573**
48	**27**	.34960	**.22367**	.36358	**.23098**	.37727	**.23838**	.39068	**.24586**
52	**28**	.34984	**.22379**	.36381	**.23110**	.37749	**.23850**	.39090	**.24598**
56	**29**	.35007	**.22391**	.36404	**.23123**	.37772	**.23863**	.39112	**.24611**
s	′	$3^h\ 46^m$	56°	$3^h\ 50^m$	57°	$3^h\ 54^m$	58°	$3^h\ 58^m$	59°
0	**30**	9.35031	**0.22403**	9.36427	**0.23135**	9.37794	**0.23875**	9.39134	**0.24623**
4	**31**	.35054	**.22415**	.36450	**.23147**	.37817	**.23887**	.39156	**.24636**
8	**32**	.35078	**.22427**	.36473	**.23160**	.37840	**.23900**	.39178	**.24648**
12	**33**	.35101	**.22440**	.36496	**.23172**	.37862	**.23912**	.39201	**.24661**
16	**34**	.35125	**.22462**	.36519	**.23184**	.37885	**.23925**	.39223	**.24673**
20	**35**	9.35148	**0.22464**	9.36542	**0.23196**	9.37907	**0.23937**	9.39245	**0.24686**
24	**36**	.35172	**.22476**	.36565	**.23209**	.37930	**.23950**	.39267	**.24698**
28	**37**	.35195	**.22488**	.36588	**.23221**	.37952	**.23962**	.39289	**.24711**
32	**38**	.35219	**.22500**	.36611	**.23233**	.37975	**.23974**	.39311	**.24723**
36	**39**	.35242	**.22512**	.36634	**.23246**	.37997	**.23987**	.39333	**.24736**
40	**40**	9.35266	**0.22525**	9.36657	**0.23258**	9.38020	**0.23999**	9.39355	**0.24749**
44	**41**	.35289	**.22637**	.36680	**.23270**	.38042	**.24012**	.39377	**.24761**
48	**42**	.35312	**.22549**	.36703	**.23282**	.38065	**.24024**	.39399	**.24774**
52	**43**	.35336	**.22561**	.36726	**.23295**	.38087	**.24036**	.39421	**.24786**
56	**44**	.35359	**.22673**	.36749	**.23307**	.38110	**.24049**	.39443	**.24799**
s	′	$3^h\ 47^m$	66°	$3^h\ 51^m$	67°	$3^h\ 55^m$	58°	$3^h\ 59^m$	69°
0	**45**	9.35383	**0.22585**	9.36772	**0.23319**	9.38132	**0.24061**	9.39465	**0.24811**
4	**46**	.35406	**.22598**	.36794	**.23332**	.38154	**.24074**	.39487	**.24824**
8	**47**	.35429	**.22610**	.36817	**.23344**	.38177	**.24086**	.39509	**.24836**
12	**48**	.35453	**.22622**	.36840	**.23356**	.38199	**.24099**	.39531	**.24849**
16	**49**	.35476	**.22634**	.36863	**.23368**	.38222	**.24111**	.39553	**.24862**
20	**50**	9.35500	**0.22646**	9.36886	**0.23381**	9.38244	**0.24124**	9.39575	**0.24874**
24	**51**	.35523	**.22658**	.36909	**.23393**	.38267	**.24136**	.39597	**.24887**
28	**52**	.35546	**.22671**	.36932	**.23405**	.38289	**.24148**	.39619	**.24899**
32	**53**	.35570	**.22683**	.36955	**.23418**	.38311	**.24161**	.39641	**.24912**
36	**54**	.35593	**.22695**	.36977	**.23430**	.38334	**.24173**	.39663	**.24924**
40	**55**	9.35616	**0.22707**	9.37000	**0.23442**	9.38356	**0.24186**	9.39685	**0.24937**
44	**56**	.35639	**.22719**	.37023	**.23455**	.38378	**.24198**	.39706	**.24950**
48	**57**	.35663	**.22731**	.37046	**.23467**	.38401	**.24211**	.39728	**.24962**
52	**58**	.35686	**.22744**	.37069	**.23479**	.38423	**.24223**	.39750	**.24975**
56	**59**	.35709	**.22756**	.37091	**.23492**	.38445	**.24236**	.39772	**.24987**
60	**60**	9.35733	**0.22768**	9.37114	**0.23504**	9.38468	**0.24248**	9.39794	**0.25000**

Table 10. Haversine Table

s	′	$4^h\,0^m$ Hav.	60° No.	$4^h\,4^m$ Hav.	61° No.	$4^h\,8^m$ Hav.	62° No.	$4^h\,12^m$ Hav.	63° No.
0	0	9.39794	0.25000	9.41094	0.25760	9.42368	0.26526	9.43617	0.27300
4	1	.39816	.25013	.41115	.25772	.42389	.26539	.43638	.27313
8	2	.39838	.25025	.41137	.25785	.42410	.26552	.43658	.27326
12	3	.39860	.25038	.41158	.25798	.42431	.26565	.43679	.27339
16	4	.39881	.25050	.41180	.25810	.42452	.26578	.43699	.27352
20	5	9.39903	0.25063	9.41201	0.25823	9.42473	0.26591	9.43720	0.27365
24	6	.39925	.25076	.41222	.25836	.42494	.26604	.43741	.27378
28	7	.39947	.25088	.41244	.25849	.42515	.26616	.43761	.27391
32	8	.39969	.25101	.41265	.25861	.42536	.26629	.43782	.27404
36	9	.39991	.25113	.41287	.25874	.42557	.26642	.43802	.27417
40	10	9.40012	0.25126	9.41308	0.25887	9.42578	0.26655	9.43823	0.27430
44	11	.40034	.25139	.41329	.25900	.42599	.26668	.43843	.27443
48	12	.40056	.25151	.41351	.25912	.42620	.26681	.43864	.27456
52	13	.40078	.25164	.41372	.25925	.42641	.26694	.43884	.27469
56	14	.40100	.25177	.41393	.25938	.42662	.26706	.43905	.27482

s	′	$4^h\,1^m$ Hav.	60° No.	$4^h\,5^m$ Hav.	61° No.	$4^h\,9^m$ Hav.	62° No.	$4^h\,13^m$ Hav.	63° No.
0	15	9.40121	0.25189	9.41415	0.25951	9.42682	0.26719	9.43926	0.27495
4	16	.40143	.25202	.41436	.25963	.42703	.26732	.43946	.27508
8	17	.40165	.25214	.41457	.25976	.42724	.26745	.43967	.27521
12	18	.40187	.25227	.41479	.25989	.42745	.26758	.43987	.27534
16	19	.40208	.25240	.41500	.26002	.42766	.26771	.44008	.27547
20	20	9.40230	0.25252	9.41521	0.26014	9.42787	0.26784	9.44028	0.27560
24	21	.40252	.25265	.41543	.26027	.42808	.26797	.44048	.27573
28	22	.40274	.25278	.41564	.26040	.42829	.26809	.44069	.27586
32	23	.40295	.25290	.41585	.26053	.42850	.26822	.44089	.27599
36	24	.40317	.25303	.41606	.26065	.42870	.26835	.44110	.27612
40	25	9.40339	0.25316	9.41628	0.26078	9.42891	0.26848	9.44130	0.27625
44	26	.40360	.25328	.41649	.26091	.42912	.26861	.44151	.27638
48	27	.40382	.25341	.41670	.26104	.42933	.26874	.44171	.27651
52	28	.40404	.25354	.41692	.26117	.42954	.26887	.44192	.27664
56	29	.40425	.25366	.41713	.26129	.42975	.26900	.44212	.27677

s	′	$4^h\,2^m$ Hav.	60° No.	$4^h\,6^m$ Hav.	61° No.	$4^h\,10^m$ Hav.	62° No.	$4^h\,14^m$ Hav.	63° No.
0	30	9.40447	0.25379	9.41734	0.26142	9.42996	0.26913	9.44232	0.27690
4	31	.40469	.25391	.41755	.26155	.43016	.26925	.44253	.27703
8	32	.40490	.25404	.41776	.26168	.43037	.26938	.44273	.27716
12	33	.40512	.25417	.41798	.26180	.43058	.26951	.44294	.27729
16	34	.40534	.25429	.41819	.26193	.43079	.26964	.44314	.27742
20	35	9.40555	0.25442	9.41840	0.26206	9.43100	0.26977	9.44334	0.27755
24	36	.40577	.25455	.41861	.26219	.43120	.26990	.44355	.27768
28	37	.40599	.25467	.41882	.26232	.43141	.27003	.44375	.27781
32	38	.40620	.25480	.41904	.26244	.43162	.27016	.44396	.27794
36	39	.40642	.25493	.41925	.26257	.43183	.27029	.44416	.27807
40	40	9.40663	0.25506	9.41946	0.26270	9.43203	0.27042	9.44436	0.27820
44	41	.40685	.25518	.41967	.26283	.43224	.27055	.44457	.27833
48	42	.40707	.25531	.41988	.26296	.43245	.27068	.44477	.27846
52	43	.40728	.25544	.42009	.26308	.43266	.27080	.44497	.27859
56	44	.40750	.25556	.42031	.26321	.43286	.27093	.44518	.27873

s	′	$4^h\,3^m$ Hav.	60° No.	$4^h\,7^m$ Hav.	61° No.	$4^h\,11^m$ Hav.	62° No.	$4^h\,15^m$ Hav.	63° No.
0	45	9.40771	0.25569	9.42052	0.26334	9.43307	0.27106	9.44538	0.27886
4	46	.40793	.25582	.42073	.26347	.43328	.27119	.44558	.27899
8	47	.40814	.25594	.42094	.26360	.43348	.27132	.44579	.27912
12	48	.40836	.25607	.42115	.26372	.43369	.27145	.44599	.27925
16	49	.40858	.25620	.42136	.26385	.43390	.27158	.44619	.27938
20	50	9.40879	0.25632	9.42157	0.26398	9.43411	0.27171	9.44639	0.27951
24	51	.40900	.25645	.42178	.26411	.43431	.27184	.44660	.27964
28	52	.40922	.25658	.42199	.26424	.43452	.27197	.44680	.27977
32	53	.40943	.25671	.42221	.26437	.43473	.27210	.44700	.27990
36	54	.40965	.25683	.42242	.26449	.43493	.27223	.44721	.28003
40	55	9.40986	0.25696	9.42263	0.26462	9.43514	0.27236	9.44741	0.28016
44	56	.41008	.25709	.42284	.26475	.43535	.27249	.44761	.28029
48	57	.41029	.25721	.42305	.26488	.43555	.27262	.44781	.28042
52	58	.41051	.25734	.42326	.26501	.43576	.27275	.44801	.28055
56	59	.41072	.25747	.42347	.26514	.43596	.27288	.44822	.28068
60	60	9.41094	0.25760	9.42368	0.26526	9.43617	0.27300	9.44842	0.28081

s	′	$4^h\ 16^m$	64°	$4^h\ 20^m$	65°	$4^h\ 24^m$	66°	$4^h\ 28^m$	67°
		Hav.	No.	Hav.	No.	Hav.	No.	Hav.	No.
0	0	9.44842	0.28081	9.46043	0.28869	9.47222	0.29663	9.48378	0.30463
4	1	.44862	.28095	.46063	.28882	.47241	.29676	.48397	.30477
8	2	.44882	.28108	.46083	.28895	.47261	.29690	.48416	.30490
12	3	.44903	.28121	.46103	.28909	.47280	.29703	.48435	.30504
16	4	.44923	.28134	.46123	.28922	.47300	.29716	.48454	.30517
20	5	9.44943	0.28147	9.46142	0.28935	9.47319	0.29730	9.48473	0.30530
24	6	.44963	.28160	.46162	.28948	.47338	.29743	.48492	.30544
28	7	.44983	.28173	.46182	.28961	.47358	.29756	.48511	.30557
32	8	.45003	.28186	.46202	.28975	.47377	.29770	.48530	.30571
36	9	.45024	.28199	.46222	.28988	.47397	.29783	.48549	.30584
40	10	9.45044	0.28212	9.46241	0.29001	9.47416	0.29796	9.48568	0.30597
44	11	.45064	.28225	.46261	.29014	.47435	.29809	.48587	.30611
48	12	.45084	.28238	.46281	.29027	.47455	.29823	.48607	.30624
52	13	.45104	.28252	.46301	.29041	.47474	.29836	.48626	.30638
56	14	.45124	.28265	.46320	.29054	.47493	.29849	.48645	.30651
s	′	$4^h\ 17^m$	64°	$4^h\ 21^m$	65°	$4^h\ 25^m$	66°	$4^h\ 29^m$	67°
0	15	9.45144	0.28278	9.46340	0.29067	9.47513	0.29863	9.48664	0.30664
4	16	.45165	.28291	.46360	.29080	.47532	.29876	.48683	.30678
8	17	.45185	.28304	.46380	.29093	.47552	.29889	.48702	.30691
12	18	.45205	.28317	.46399	.29107	.47571	.29903	.48720	.30705
16	19	.45225	.28330	.46419	.29120	.47590	.29916	.48739	.30718
20	20	9.45245	0.28343	9.46439	0.29133	9.47610	0.29929	9.48758	0.30732
24	21	.45265	.28356	.46458	.29146	.47629	.29943	.48777	.30745
28	22	.45285	.28369	.46478	.29160	.47648	.29956	.48796	.30758
32	23	.45305	.28383	.46498	.29173	.47668	.29969	.48815	.30772
36	24	.45325	.28396	.46517	.29186	.47687	.29983	.48834	.30785
40	25	9.45345	0.28409	9.46537	0.29199	9.47706	0.29996	9.48853	0.30799
44	26	.45365	.28422	.46557	.29212	.47725	.30009	.48872	.30812
48	27	.45385	.28435	.46576	.29226	.47745	.30023	.48891	.30826
52	28	.45405	.28448	.46596	.29239	.47764	.30036	.48910	.30839
56	29	.45426	.28461	.46616	.29252	.47783	.30049	.48929	.30852
s	′	$4^h\ 18^m$	64°	$4^h\ 22^m$	65°	$4^h\ 26^m$	66°	$4^h\ 30^m$	67°
0	30	9.45446	0.28474	9.46635	0.29265	9.47803	0.30063	9.48948	0.30866
4	31	.45466	.28488	.46655	.29279	.47822	.30076	.48967	.30879
8	32	.45486	.28501	.46675	.29292	.47841	.30089	.48986	.30893
12	33	.45506	.28514	.46694	.29305	.47860	.30103	.49004	.30906
16	34	.45526	.28527	.46714	.29318	.47880	.30116	.49023	.30920
20	35	9.45546	0.28540	9.46733	0.29332	9.47899	0.30129	9.49042	0.30933
24	36	.45566	.28553	.46753	.29345	.47918	.30143	.49061	.30946
28	37	.45586	.28566	.46773	.29358	.47937	.30156	.49080	.30960
32	38	.45606	.28580	.46792	.29371	.47957	.30169	.49099	.30973
36	39	.45625	.28593	.46812	.29385	.47976	.30183	.49118	.30987
40	40	9.45645	0.28606	9.46831	0.29398	9.47995	0.30196	9.49137	0.31000
44	41	.45665	.28619	.46851	.29411	.48014	.30209	.49155	.31014
48	42	.45685	.28632	.46871	.29424	.48033	.30223	.49174	.31027
52	43	.45705	.28645	.46890	.29438	.48053	.30236	.49193	.31041
56	44	.45725	.28658	.46910	.29451	.48072	.30249	.49212	.31054
s	′	$4^h\ 19^m$	64°	$4^h\ 23^m$	65°	$4^h\ 27^m$	66°	$4^h\ 31^m$	67°
0	45	9.45745	0.28672	9.46929	0.29464	9.48091	0.30263	9.49231	0.31068
4	46	.45765	.28685	.46949	.29477	.48110	.30276	.49250	.31081
8	47	.45785	.28698	.46968	.29491	.48129	.30290	.49268	.31095
12	48	.45805	.28711	.46988	.29504	.48148	.30303	.49287	.31108
16	49	.45825	.28724	.47007	.29517	.48168	.30316	.49306	.31121
20	50	9.45845	0.28737	9.47027	0.29530	9.48187	0.30330	9.49325	0.31135
24	51	.45865	.28751	.47046	.29544	.48206	.30343	.49344	.31148
28	52	.45884	.28764	.47066	.29557	.48225	.30356	.49362	.31162
32	53	.45904	.28777	.47085	.29570	.48244	.30370	.49481	.31175
36	54	.45924	.28790	.47105	.29583	.48263	.30383	.49400	.31189
40	55	9.45944	0.28803	9.47124	0.29597	9.48282	0.30397	9.49419	0.31202
44	56	.45964	.28816	.47144	.29610	.48302	.30410	.49437	.31216
48	57	.45984	.28830	.47163	.29623	.48321	.30423	.49456	.31229
52	58	.46004	.28843	.47183	.29637	.48340	.30437	.49475	.31243
56	59	.46023	.28856	.47202	.29650	.48359	.30450	.49494	.31256
60	60	9.46043	0.28869	9.47222	0.29663	9.48378	0.30463	9.49512	0.31270

s	′	$4^h\,32^m$	68°	$4^h\,36^m$	69°	$4^h\,40^m$	70°	$4^h\,44^m$	71°
		Hav.	No.	Hav.	No.	Hav.	No.	Hav.	No.
0	0	9.49512	0.31270	9.50626	0.32082	9.51718	0.32899	9.52791	0.33722
4	1	.49531	.31283	.50644	.32095	.51736	.32913	.52809	.33735
8	2	.49550	.31297	.50662	.32109	.51754	.32926	.52826	.33749
12	3	.49568	.31310	.50681	.32122	.51772	.32940	.52844	.33763
16	4	.49587	.31324	.50699	.32136	.51790	.32954	.52862	.33777
20	5	9.49606	0.31337	9.50717	0.32150	9.51808	0.32967	9.52879	0.33790
24	6	.49625	.31351	.50736	.32163	.51826	.32981	.52897	.33804
28	7	.49643	.31364	.50754	.32177	.51844	.32995	.52915	.33818
32	8	.49662	.31378	.50772	.32190	.51862	.33008	.52932	.33832
36	9	.49681	.31391	.50791	.32204	.51880	.33022	.52950	.33845
40	10	9.49699	0.31405	9.50809	0.32217	9.51898	0.33036	9.52968	0.33859
44	11	.49718	.31418	.50827	.32231	.51916	.33049	.52985	.33873
48	12	.49737	.31432	.50846	.32245	.51934	.33063	.53003	.33887
52	13	.49755	.31445	.50864	.32258	.51952	.33077	.53021	.33900
56	14	.49774	.31459	.50882	.32272	.51970	.33090	.53038	.33914
s	′	$4^h\,33^m$	68°	$4^h\,37^m$	69°	$4^h\,41^m$	70°	$4^h\,45^m$	71°
0	15	9.49793	0.31472	9.50901	0.32285	9.51988	0.33104	9.53056	0.33928
4	16	.49811	.31486	.50919	.32299	.52006	.33118	.53073	.33942
8	17	.49830	.31499	.50937	.32313	.52024	.33132	.53091	.33956
12	18	.49849	.31513	.50956	.32326	.52042	.33145	.53109	.33969
16	19	.49867	.31526	.50974	.32340	.52060	.33159	.53126	.33983
20	20	9.49886	0.31540	9.50992	0.32353	9.52078	0.33173	9.53144	0.33997
24	21	.49904	.31553	.51010	.32367	.52096	.33186	.53162	.34011
28	22	.49923	.31567	.51029	.32381	.52114	.33200	.53179	.34024
32	23	.49942	.31580	.51047	.32394	.52132	.33214	.53197	.34038
36	24	.49960	.31594	.51065	.32408	.52150	.33227	.53214	.34052
40	25	9.49979	0.31607	9.51083	0.32422	9.52168	0.33241	9.53232	0.34066
44	26	.49997	.31621	.51102	.32435	.52185	.33255	.53249	.34080
48	27	.50016	.31634	.51120	.32449	.52203	.33269	.53267	.34093
52	28	.50034	.31648	.51138	.32462	.52221	.33282	.53285	.34107
56	29	.50053	.31661	.51156	.32476	.52239	.33296	.53302	.34121
s	′	$4^h\,34^m$	68°	$4^h\,38^m$	69°	$4^h\,42^m$	70°	$4^h\,46^m$	71°
0	30	9.50072	0.31675	9.51174	0.32490	9.52257	0.33310	9.53320	0.34135
4	31	.50090	.31688	.51193	.32503	.52275	.33323	.53337	.34149
8	32	.50109	.31702	.51211	.32517	.52293	.33337	.53355	.34162
12	33	.50127	.31716	.51229	.32531	.52311	.33351	.53372	.34176
16	34	.50146	.31729	.51247	.32544	.52328	.33365	.53390	.34190
20	35	9.50164	0.31742	9.51265	0.32558	9.52346	0.33378	9.53407	0.34204
24	36	.50183	.31756	.51284	.32571	.52364	.33392	.53425	.34218
28	37	.50201	.31770	.51302	.32585	.52382	.33406	.53442	.34231
32	38	.50220	.31783	.51320	.32599	.52400	.33419	.53460	.34245
36	39	.50238	.31797	.51338	.32612	.52418	.33433	.53477	.34259
40	40	9.50257	0.31810	9.51356	0.32626	9.52436	0.33447	9.53495	0.34273
44	41	.50275	.31824	.51374	.32640	.52453	.33461	.53512	.34287
48	42	.50294	.31837	.51393	.32653	.52471	.33474	.53530	.34300
52	43	.50312	.31851	.51411	.32667	.52489	.33488	.53547	.34314
56	44	.50331	.31865	.51429	.32681	.52507	.33502	.53565	.34328
s	′	$4^h\,35^m$	68°	$4^h\,39^m$	69°	$4^h\,43^m$	70°	$4^h\,47^m$	71°
0	45	9.50349	0.31878	9.51447	0.32694	9.52525	0.33515	9.53582	0.34342
4	46	.50368	.31892	.51465	.32708	.52542	.33529	.53600	.34356
8	47	.50386	.31905	.51483	.32721	.52560	.33543	.53617	.34369
12	48	.50405	.31919	.51501	.32735	.52578	.33557	.53635	.34383
16	49	.50423	.31932	.51519	.32749	.52596	.33570	.53652	.34397
20	50	9.50442	0.31946	9.51538	0.32762	9.52613	0.33584	9.53670	0.34411
24	51	.50460	.31959	.51556	.32776	.52631	.33598	.53687	.34425
28	52	.50478	.31973	.51574	.32790	.52649	.33612	.53704	.34439
32	53	.50497	.31987	.51592	.32803	.52667	.33625	.53722	.34452
36	54	.50515	.32000	.51610	.32817	.52684	.33639	.53739	.34466
40	55	9.50534	0.32014	9.51628	0.32831	9.52702	0.33653	9.53757	0.34480
44	56	.50552	.32027	.51646	.32844	.52720	.33667	.53774	.34494
48	57	.50570	.32041	.51664	.32858	.52738	.33680	.53792	.34508
52	58	.50589	.32054	.51682	.32872	.52755	.33694	.53809	.34521
56	59	.50607	.32068	.51700	.32885	.52773	.33708	.53826	.34535
60	60	9.50626	0.32082	9.51718	0.32899	9.52791	0.33722	9.53844	0.34549

s	′	$4^h\,48^m$ Hav.	72° No.	$4^h\,52^m$ Hav.	73° No.	$4^h\,56^m$ Hav.	74° No.	$5^h\,0^m$ Hav.	75° No.
0	**0**	9.53844	**0.34549**	9.54878	**0.35381**	9.55893	**0.36218**	9.56889	**0.37059**
4	**1**	.53861	**.34563**	.54895	**.35395**	.55909	**.36232**	.56906	**.37073**
8	**2**	.53879	**.34577**	.54912	**.35409**	.55926	**.36246**	.56922	**.37087**
12	**3**	.53896	**.34591**	.54929	**.35423**	.55943	**.36260**	.56939	**.37101**
16	**4**	.53913	**.34604**	.54946	**.35437**	.55960	**.36274**	.56955	**.37115**
20	**5**	9.53931	**0.34618**	9.54963	**0.35451**	9.55976	**0.36288**	9.56972	**0.37129**
24	**6**	.53948	**.34632**	.54980	**.35465**	.55993	**.36302**	.56988	**.37143**
28	**7**	.53966	**.34646**	.54997	**.35479**	.56010	**.36316**	.57005	**.37157**
32	**8**	.53983	**.34660**	.55014	**.35493**	.56027	**.36330**	.57021	**.37171**
36	**9**	.54000	**.34674**	.55031	**.35507**	.56043	**.36344**	.57037	**.37186**
40	**10**	9.54017	**0.34688**	9.55048	**0.35521**	9.56060	**0.36358**	9.57054	**0.37200**
44	**11**	.54035	**.34701**	.55065	**.35534**	.56077	**.36372**	.57070	**.37214**
48	**12**	.54052	**.34715**	.55082	**.35548**	.56093	**.36386**	.57087	**.37228**
52	**13**	.54069	**.34729**	.55099	**.35562**	.56110	**.36400**	.57103	**.37242**
56	**14**	.54087	**.34743**	.55116	**.35576**	.56127	**.36414**	.57119	**.37256**
s	′	$4^h\,49^m$	72°	$4^h\,53^m$	73°	$4^h\,57^m$	74°	$5^h\,1^m$	75°
0	**15**	9.54104	**0.34757**	9.55133	**0.35590**	9.56144	**0.36428**	9.57136	**0.37270**
4	**16**	.54121	**.34771**	.55150	**.35604**	.56160	**.36442**	.57152	**.37284**
8	**17**	.54139	**.34784**	.55167	**.35618**	.56177	**.36456**	.57169	**.37298**
12	**18**	.54156	**.34798**	.55184	**.35632**	.56194	**.36470**	.57185	**.37312**
16	**19**	.54173	**.34812**	.55201	**.35646**	.56210	**.36484**	.57201	**.37326**
20	**20**	9.54190	**0.34826**	9.55218	**0.35660**	9.56227	**0.36498**	9.57218	**0.37340**
24	**21**	.54208	**.34840**	.55235	**.35674**	.56244	**.36512**	.57234	**.37354**
28	**22**	.54225	**.34854**	.55252	**.35688**	.56260	**.36526**	.57250	**.37368**
32	**23**	.54242	**.34868**	.55269	**.35702**	.56277	**.36540**	.57267	**.37382**
36	**24**	.54260	**.34882**	.55286	**.35716**	.56294	**.36554**	.57283	**.37397**
40	**25**	9.54277	**0.34895**	9.55303	**0.35730**	9.56310	**0.36568**	9.57299	**0.37411**
44	**26**	.54294	**.34909**	.55320	**.35743**	.56327	**.36582**	.57316	**.37425**
48	**27**	.54311	**.34923**	.55337	**.35757**	.56343	**.36596**	.57332	**.37439**
52	**28**	.54329	**.34937**	.55354	**.35771**	.56360	**.36610**	.57348	**.37453**
56	**29**	.54346	**.34951**	.55370	**.35785**	.56377	**.36624**	.57365	**.37467**
s	′	$4^h\,50^m$	72°	$4^h\,54^m$	73°	$4^h\,58^m$	74°	$5^h\,2^m$	75°
0	**30**	9.54363	**0.34965**	9.55387	**0.35799**	9.56393	**0.36638**	9.57381	**0.37481**
4	**31**	.54380	**.34979**	.55404	**.35813**	.56410	**.36652**	.57397	**.37495**
8	**32**	.54397	**.34992**	.55421	**.35827**	.56426	**.36666**	.57414	**.37509**
12	**33**	.54415	**.35006**	.55438	**.35841**	.56443	**.36680**	.57430	**.37523**
16	**34**	.54432	**.35020**	.55455	**.35855**	.56460	**.36694**	.57446	**.37537**
20	**35**	9.54449	**0.35034**	9.55472	**0.35869**	9.56476	**0.36708**	9.57463	**0.37551**
24	**36**	.54466	**.35048**	.55489	**.35883**	.56493	**.36722**	.57479	**.37566**
28	**37**	.54483	**.35062**	.55506	**.35897**	.56509	**.36736**	.57495	**.37580**
32	**38**	.54501	**.35076**	.55523	**.35911**	.56526	**.36750**	.57511	**.37594**
36	**39**	.54518	**.35090**	.55539	**.35925**	.56543	**.36764**	.57528	**.37608**
40	**40**	9.54535	**0.35103**	9.55556	**0.35939**	9.56559	**0.36778**	9.57544	**0.37622**
44	**41**	.54552	**.35117**	.55573	**.35953**	.56576	**.36792**	.57560	**.37636**
48	**42**	.54569	**.35131**	.55590	**.35967**	.56592	**.36806**	.57577	**.37650**
52	**43**	.54587	**.35145**	.55607	**.35981**	.56609	**.36820**	.57593	**.37664**
56	**44**	.54604	**.35159**	.55624	**.35995**	.56625	**.36834**	.57609	**.37678**
s	′	$4^h\,51^m$	72°	$4^h\,55^m$	73°	$4^h\,59^m$	74°	$5^h\,3^m$	75°
0	**45**	9.54621	**0.35173**	9.55641	**0.36009**	9.56642	**0.36848**	9.57625	**0.37692**
4	**46**	.54638	**.35187**	.55657	**.36023**	.56658	**.36862**	.57642	**.37706**
8	**47**	.54655	**.35201**	.55674	**.36036**	.56675	**.36877**	.57658	**.37721**
12	**48**	.54672	**.35215**	.55691	**.36050**	.56692	**.36891**	.57674	**.37735**
16	**49**	.54689	**.35228**	.55708	**.36064**	.56708	**.36905**	.57690	**.37749**
20	**50**	9.54707	**0.35242**	9.55725	**0.36078**	9.56725	**0.36919**	9.57706	**0.37763**
24	**51**	.54724	**.35256**	.55742	**.36092**	.56741	**.36933**	.57723	**.37777**
28	**52**	.54741	**.35270**	.55758	**.36106**	.56758	**.36947**	.57739	**.37791**
32	**53**	.54758	**.35284**	.55775	**.36120**	.56774	**.36961**	.57755	**.37805**
36	**54**	.54775	**.35298**	.55792	**.36134**	.56791	**.36975**	.57771	**.37819**
40	**55**	9.54792	**0.35312**	9.55809	**0.36148**	9.56807	**0.36989**	9.57787	**0.37833**
44	**56**	.54809	**.35326**	.55826	**.36162**	.56824	**.37003**	.57804	**.37847**
48	**57**	.54826	**.35340**	.55842	**.36176**	.56840	**.37017**	.57820	**.37862**
52	**58**	.54843	**.35354**	.55859	**.36190**	.56856	**.37031**	.57836	**.37876**
56	**59**	.54860	**.35368**	.55876	**.36204**	.56873	**.37045**	.57852	**.37890**
60	**60**	9.54878	**0.35381**	9.55893	**0.36218**	9.56889	**0.37059**	9.57868	**0.37904**

s	′	$5^h\ 4^m$ Hav.	76° No.	$5^h\ 8^m$ Hav.	77° No.	$5^h\ 12^m$ Hav.	78° No.	$5^h\ 16^m$ Hav.	79° No.
0	0	9.57868	0.37904	9.58830	0.38752	9.59774	0.39604	9.60702	0.40460
4	1	.57885	.37918	.58846	.38767	.59790	.39619	.60717	.40474
8	2	.57901	.37932	.58862	.38781	.59806	.39633	.60733	.40488
12	3	.57917	.37946	.58878	.38795	.59821	.39647	.60748	.40502
16	4	.57933	.37960	.58893	.38809	.59837	.39661	.60763	.40517
20	5	9.57949	0.37974	9.58909	0.38823	9.59852	0.39676	9.60779	0.40531
24	6	.57965	.37989	.58925	.38837	.59868	.39690	.60794	.40545
28	7	.57981	.38003	.58941	.38852	.59883	.39704	.60809	.40560
32	8	.57998	.38017	.58957	.38866	.59899	.39718	.60825	.40574
36	9	.58014	.38031	.58973	.38880	.59915	.39732	.60840	.40588
40	10	9.58030	0.38045	9.58989	0.38894	9.59930	0.39746	9.60855	0.40602
44	11	.58046	.38059	.59004	.38908	.59946	.39761	.60870	.40617
48	12	.58062	.38073	.59020	.38923	.59961	.39775	.60886	.40631
52	13	.58078	.38087	.59036	.38937	.59977	.39789	.60901	.40645
56	14	.58094	.38102	.59052	.38951	.59992	.39803	.60916	.40660
s	′	$5^h\ 5^m$	76°	$5^h\ 9^m$	77°	$5^h\ 13^m$	78°	$5^h\ 17^m$	79°
0	15	9.58110	0.38116	9.59068	0.38965	9.60008	0.39818	9.60931	0.40674
4	16	.58126	.38130	.59083	.38979	.60023	.39832	.60947	.40688
8	17	.58143	.38144	.59099	.38994	.60039	.39846	.60962	.40702
12	18	.58159	.38158	.59115	.39008	.60054	.39861	.60977	.40717
16	19	.58175	.38172	.59131	.39022	.60070	.39875	.60992	.40731
20	20	9.58191	0.38186	9.59147	0.39036	9.60085	0.39889	9.61008	0.40745
24	21	.58207	.38200	.59162	.39050	.60101	.39903	.61023	.40760
28	22	.58223	.38215	.59178	.39064	.60116	.39918	.61038	.40774
32	23	.58239	.38229	.59194	.39079	.60132	.39932	.61053	.40788
36	24	.58255	.38243	.59210	.39093	.60147	.39946	.61069	.40802
40	25	9.58271	0.38257	9.59225	0.39107	9.60163	0.39960	9.61084	0.40817
44	26	.58287	.38271	.59241	.39121	.60178	.39975	.61099	.40831
48	27	.58303	.38285	.59257	.39135	.60194	.39989	.61114	.40845
52	28	.58319	.38299	.59273	.39150	.60209	.40003	.61129	.40860
56	29	.58335	.38314	.59289	.39164	.60225	.40017	.61145	.40874
s	′	$5^h\ 6^m$	76°	$5^h\ 10^m$	77°	$5^h\ 14^m$	78°	$5^h\ 18^m$	79°
0	30	9.58351	0.38328	9.59304	0.39178	9.60240	0.40032	9.61160	0.40888
4	31	.58367	.38342	.59320	.39192	.60256	.40046	.61175	.40903
8	32	.58383	.38356	.59336	.39206	.60271	.40060	.61190	.40917
12	33	.58399	.38370	.59351	.39221	.60287	.40074	.61205	.40931
16	34	.58415	.38384	.59367	.39235	.60302	.40089	.61221	.40945
20	35	9.58431	0.38398	9.59383	0.39249	9.60318	0.40103	9.61236	0.40960
24	36	.58447	.38413	.59399	.39263	.60333	.40117	.61251	.40974
28	37	.58463	.38427	.59414	.39277	.60348	.40131	.61266	.40988
32	38	.58479	.38441	.59430	.39292	.60364	.40146	.61281	.41003
36	39	.58495	.38455	.59446	.39306	.60379	.40160	.61296	.41017
40	40	9.58511	0.38469	9.59461	0.39320	9.60395	0.40174	9.61312	0.41031
44	41	.58527	.38483	.59477	.39334	.60410	.40188	.61327	.41046
48	42	.58543	.38498	.59493	.39348	.60426	.40203	.61342	.41060
52	43	.58559	.38512	.59508	.39363	.60441	.40217	.61357	.41074
56	44	.58575	.38526	.59524	.39377	.60456	.40231	.61372	.41089
s	′	$5^h\ 7^m$	76°	$5^h\ 11^m$	77°	$5^h\ 15^m$	78°	$5^h\ 19^m$	79°
0	45	9.58591	0.38540	9.59540	0.39391	9.60472	0.40245	9.61387	0.41103
4	46	.58607	.38554	.59556	.39405	.60487	.40260	.61402	.41117
8	47	.58623	.38568	.59571	.39420	.60502	.40274	.61417	.41131
12	48	.58639	.38582	.59587	.39434	.60518	.40288	.61433	.41146
16	49	.58655	.38597	.59602	.39448	.60533	.40303	.61448	.41160
20	50	9.58671	0.38611	9.59618	0.39462	9.60549	0.40317	9.61463	0.41174
24	51	.58687	.38625	.59634	.39476	.60564	.40331	.61478	.41189
28	52	.58703	.38639	.59649	.39491	.60579	.40345	.61493	.41203
32	53	.58719	.38653	.59665	.39505	.60595	.40360	.61508	.41217
36	54	.58735	.38667	.59681	.39519	.60610	.40374	.61523	.41232
40	55	9.58750	0.38682	9.59696	0.39533	9.60625	0.40388	9.61538	0.41246
44	56	.58766	.38696	.59712	.39548	.60641	.40402	.61553	.41260
48	57	.58782	.38710	.59728	.39562	.60656	.40417	.61568	.41275
52	58	.58798	.38724	.59743	.39576	.60671	.40431	.61583	.41289
56	59	.58814	.38738	.59759	.39590	.60687	.40445	.61598	.41303
60	60	9.58830	0.38752	9.59774	0.39604	9.60702	0.40460	9.61614	0.41318

s	′	$5^h\,20^m$	80°	$5^h\,24^m$	81°	$5^h\,28^m$	82°	$5^h\,32^m$	83°
		Hav.	No.	Hav.	No.	Hav.	No.	Hav.	No.
0	0	9.61614	**0.41318**	9.62509	**0.42178**	9.63389	**0.43041**	9.64253	**0.43907**
4	1	.61629	**.41332**	.62524	**.42193**	.63403	**.43056**	.64267	**.43921**
8	2	.61644	**.41346**	.62538	**.42207**	.63418	**.43070**	.64281	**.43935**
12	3	.61659	**.41361**	.62553	**.42221**	.63432	**.43085**	.64296	**.43950**
16	4	.61674	**.41375**	.62568	**.42236**	.63447	**.43099**	.64310	**.43964**
20	5	9.61689	**0.41389**	9.62583	**0.42250**	9.63461	**0.43113**	0.64324	**0.43979**
24	6	.61704	**.41404**	.62598	**.42264**	.63476	**.43128**	.64339	**.43993**
28	7	.61719	**.41418**	.62612	**.42279**	.63490	**.43142**	.64353	**.44008**
32	8	.61734	**.41432**	.62627	**.42293**	.63505	**.43157**	.64367	**.44022**
36	9	.61749	**.41447**	.62642	**.42308**	.63519	**.43171**	.64381	**.44036**
40	10	9.61764	**0.41461**	9.62657	**0.42322**	9.63534	**0.43185**	9.64396	**0.44051**
44	11	.61779	**.41475**	.62671	**.42336**	.63548	**.43200**	.64410	**.44065**
48	12	.61794	**.41490**	.62686	**.42351**	.63563	**.43214**	.64424	**.44080**
52	13	.61809	**.41504**	.62701	**.42365**	.63577	**.43229**	.64438	**.44094**
56	14	.61824	**.41518**	.62716	**.42379**	.63592	**.43243**	.64452	**.44109**
s	′	$5^h\,21^m$	80°	$5^h\,25^m$	81°	$5^h\,29^m$	82°	$5^h\,33^m$	83°
0	15	9.61839	**0.41533**	9.62730	**0.42394**	9.63606	**0.43257**	9.64467	**0.44123**
4	16	.61854	**.41547**	.62745	**.42408**	.63621	**.43272**	.64481	**.44138**
8	17	.61869	**.41561**	.62760	**.42423**	.63635	**.43286**	.64495	**.44152**
12	18	.61884	**.41576**	.62774	**.42437**	.63649	**.43301**	.64509	**.44166**
16	19	.61899	**.41590**	.62789	**.42451**	.63664	**.43315**	.64523	**.44181**
20	20	9.61914	**0.41604**	9.62804	**0.42466**	9.63678	**0.43330**	9.64538	**0.44195**
24	21	.61929	**.41619**	.62819	**.42480**	.63693	**.43344**	.64552	**.44210**
28	22	.61944	**.41633**	.62833	**.42494**	.63707	**.43358**	.64566	**.44224**
32	23	.61959	**.41647**	.62848	**.42509**	.63722	**.43373**	.64580	**.44239**
36	24	.61974	**.41662**	.62863	**.42523**	.63736	**.43387**	.64594	**.44253**
40	25	9.61989	**0.41676**	9.62877	**0.42538**	9.63751	**0.43402**	9.64609	**0.44268**
44	26	.62003	**.41690**	.62892	**.42552**	.63765	**.43416**	.64623	**.44282**
48	27	.62018	**.41705**	.62907	**.42566**	.63779	**.43430**	.64637	**.44296**
52	28	.62033	**.41719**	.62921	**.42581**	.63794	**.43445**	.64651	**.44311**
56	29	.62048	**.41733**	.62936	**.42595**	.63808	**.43459**	.64665	**.44325**
s	′	$5^h\,22^m$	80°	$5^h\,26^m$	81°	$5^h\,30^m$	82°	$5^h\,34^m$	83°
0	30	9.62063	**0.41748**	9.62951	**0.42610**	9.63823	**0.43474**	9.64679	**0.44340**
4	31	.62078	**.41762**	.62965	**.42624**	.63837	**.43488**	.64694	**.44354**
8	32	.62093	**.41776**	.62980	**.42638**	.63851	**.43503**	.64708	**.44369**
12	33	.62108	**.41791**	.62995	**.42653**	.63866	**.43517**	.64722	**.44383**
16	34	.62123	**.41805**	.63009	**.42667**	.63880	**.43531**	.64736	**.44398**
20	35	9.62138	**0.41819**	9.63024	**0.42681**	9.63895	**0.43546**	9.64750	**0.44412**
24	36	.62153	**.41834**	.63039	**.42696**	.63909	**.43560**	.64764	**.44427**
28	37	.62168	**.41848**	.63063	**.42710**	.63923	**.43575**	.64778	**.44441**
32	38	.62182	**.41862**	.63068	**.42725**	.63938	**.43589**	.64793	**.44455**
36	39	.62197	**.41877**	.63082	**.42739**	.63952	**.43603**	.64807	**.44470**
40	40	9.62212	**0.41891**	9.63097	**0.42753**	9.63966	**0.43618**	9.64821	**0.44484**
44	41	.62227	**.41905**	.63112	**.42768**	.63981	**.43632**	.64835	**.44499**
48	42	.62242	**.41920**	.63126	**.42782**	.63995	**.43647**	.64849	**.44513**
52	43	.62257	**.41934**	.63141	**.42797**	.64010	**.43661**	.64863	**.44528**
56	44	.62272	**.41949**	.63156	**.42811**	.64024	**.43676**	.64877	**.44542**
s	′	$5^h\,23^m$	80°	$5^h\,27^m$	81°	$5^h\,31^m$	82°	$5^h\,35^m$	83°
0	45	9.62287	**0.41963**	9.63170	**0.42825**	9.64038	**0.43690**	9.64891	**0.44557**
4	46	.62301	**.41977**	.63185	**.42840**	.64053	**.43704**	.64905	**.44571**
8	47	.62316	**.41992**	.63199	**.42854**	.64067	**.43719**	.64919	**.44586**
12	48	.62331	**.42006**	.63214	**.42869**	.64081	**.43733**	.64934	**.44600**
16	49	.62346	**.42020**	.63228	**.42883**	.64096	**.43748**	.64948	**.44614**
20	50	9.62361	**0.42035**	9.63243	**0.42897**	9.64110	**0.43762**	9.64962	**0.44629**
24	51	.62376	**.42049**	.63258	**.42912**	.64124	**.43777**	.64976	**.44643**
28	52	.62390	**.42063**	.63272	**.42926**	.64139	**.43791**	.64990	**.44658**
32	53	.62405	**.42078**	.63287	**.42941**	.64153	**.43805**	.65004	**.44672**
36	54	.62420	**.42092**	.63301	**.42955**	.64167	**.43820**	.65018	**.44687**
40	55	9.62435	**0.42106**	9.63316	**0.42969**	9.64181	**0.43834**	9.65032	**0.44701**
44	56	.62450	**.42121**	.63330	**.42984**	.64196	**.43849**	.65046	**.44716**
48	57	.62464	**.42135**	.63345	**.42998**	.64210	**.43863**	.65060	**.44730**
52	58	.62479	**.42150**	.63360	**.43013**	.64224	**.43878**	.65074	**.44745**
56	59	.62494	**.42164**	.63374	**.43027**	.64239	**.43892**	.65088	**.44759**
60	60	9.62509	**0.42178**	9.63389	**0.43041**	9.64253	**0.43907**	9.65102	**0.44774**

s	′	$5^h\,36^m$	84°	$5^h\,40^m$	85°	$5^h\,44^m$	86°	$5^h\,48^m$	87°
		Hav.	No.	Hav.	No.	Hav.	No.	Hav.	No.
0	0	9.65102	0.44774	9.65937	0.45642	9.66757	0.46512	9.67562	0.47383
4	1	.65116	.44788	.65950	.45657	.66770	.46527	.67576	.47398
8	2	.65130	.44803	.65964	.45671	.66784	.46541	.67589	.47412
12	3	.65144	.44817	.65978	.45686	.66797	.46556	.67602	.47427
16	4	.65158	.44831	.65992	.45700	.66811	.46570	.67616	.47441
20	5	9.65172	0.44846	9.66006	0.45715	9.66824	0.46585	9.67629	0.47456
24	6	.65186	.44860	.66019	.45729	.66838	.46599	.67642	.47470
28	7	.65200	.44875	.66033	.45744	.66851	.46614	.67656	.47485
32	8	.65214	.44889	.66047	.45758	.66865	.46628	.67669	.47499
36	9	.65228	.44904	.66061	.45773	.66878	.46643	.67682	.47514
40	10	9.65242	0.44918	9.66074	0.45787	9.66892	0.46657	9.67695	0.47528
44	11	.65256	.44933	.66088	.45802	.66905	.46672	.67709	.47543
48	12	.65270	.44947	.66102	.45816	.66919	.46686	.67722	.47558
52	13	.65284	.44962	.66116	.45831	.66932	.46701	.67735	.47572
56	14	.65298	.44976	.66129	.45845	.66946	.46715	.67748	.47587
s	′	$5^h\,37^m$	84°	$5^h\,41^m$	85°	$5^h\,45^m$	86°	$5^h\,49^m$	87°
0	15	9.65312	0.44991	9.66143	0.45860	9.66959	0.46730	9.67762	0.47601
4	16	.65326	.45005	.66157	.45874	.66973	.46744	.67775	.47616
8	17	.65340	.45020	.66170	.45889	.66986	.46759	.67788	.47630
12	18	.65354	.45034	.66184	.45903	.67000	.46773	.67801	.47645
16	19	.65368	.45048	.66198	.45918	.67013	.46788	.67815	.47659
20	20	9.65382	0.45063	9.66212	0.45932	9.67027	0.46802	9.67828	0.47674
24	21	.65396	.45077	.66225	.45947	.67040	.46817	.67841	.47688
28	22	.65410	.45092	.66239	.45961	.67054	.46831	.67854	.47703
32	23	.65424	.45106	.66253	.45976	.67067	.46846	.67868	.47717
36	24	.65438	.45121	.66266	.45990	.67081	.46860	.67881	.47732
40	25	9.65452	0.45135	9.66280	0.46005	9.67094	0.46875	9.67894	0.47746
44	26	.65466	.45150	.66294	.46019	.67108	.46890	.67907	.47761
48	27	.65480	.45164	.66307	.46034	.67121	.46904	.67920	.47775
52	28	.65493	.45179	.66321	.46048	.67134	.46919	.67934	.47790
56	29	.65507	.45193	.66335	.46063	.67148	.46933	.67947	.47805
s	′	$5^h\,38^m$	84°	$5^h\,42^m$	85°	$5^h\,46^m$	86°	$5^h\,50^m$	87°
0	30	9.65521	0.45208	9.66348	0.46077	9.67161	0.46948	9.67960	0.47819
4	31	.65535	.45222	.66362	.46092	.67175	.46962	.67973	.47834
8	32	.65549	.45237	.66376	.46106	.67188	.46977	.67986	.47848
12	33	.65563	.45251	.66389	.46121	.67202	.46991	.68000	.47863
16	34	.65577	.45266	.66403	.46135	.67215	.47006	.68013	.47877
20	35	9.65591	0.45280	9.66417	0.46150	9.67228	0.47020	9.68026	0.47892
24	36	.65605	.45295	.66430	.46164	.67242	.47035	.68039	.47906
28	37	.65619	.45309	.66444	.46179	.67255	.47049	.68052	.47921
32	38	.65632	.45324	.66458	.46193	.67269	.47064	.68066	.47935
36	39	.65646	.46338	.66471	.46208	.67282	.47078	.68079	.47950
40	40	9.65660	0.45353	9.66485	0.46222	9.67295	0.47093	9.68092	0.47964
44	41	.65674	.45367	.66499	.46237	.67309	.47107	.68105	.47979
48	42	.65688	.45381	.66512	.46251	.67322	.47122	.68118	.47993
52	43	.65702	.45396	.66526	.46266	.67336	.47136	.68131	.48008
56	44	.65716	.45410	.66539	.46280	.67349	.47151	.68144	.48022
s	′	$5^h\,39^m$	84°	$5^h\,43^m$	85°	$5^h\,47^m$	86°	$5^h\,51^m$	87°
0	45	9.65729	0.45425	9.66553	0.46295	9.67362	0.47165	9.68158	0.48037
4	46	.65743	.45439	.66567	.46309	.67376	.47180	.68171	.48052
8	47	.65757	.45454	.66580	.46324	.67389	.47194	.68184	.48066
12	48	.65771	.45468	.66594	.46338	.67402	.47209	.68197	.48081
16	49	.65785	.45483	.66607	.46353	.67416	.47223	.68210	.48095
20	50	9.65799	0.45497	9.66621	0.46367	9.67429	0.47238	9.68223	0.48110
24	51	.65812	.45512	.66635	.46382	.67443	.47252	.68236	.48124
28	52	.65826	.45526	.66648	.46396	.67456	.47267	.68249	.48139
32	53	.65840	.45541	.66662	.46411	.67469	.47282	.68263	.48153
36	54	.65854	.45555	.66675	.46425	.67483	.47296	.68276	.48168
40	55	9.65868	0.45570	9.66689	0.46440	9.67496	0.47311	9.68289	0.48182
44	56	.65881	.45584	.66702	.46454	.67509	.47325	.68302	.48197
48	57	.65895	.45599	.66716	.46469	.67522	.47340	.68315	.48211
52	58	.65909	.45613	.66730	.46483	.67536	.47354	.68328	.48226
56	59	.65923	.45628	.66743	.46498	.67549	.47369	.68341	.48241
60	60	9.65937	0.45642	9.66757	0.46512	9.67562	0.47383	9.68354	0.48255

Table 10. Haversine Table

s	′	5h 52m Hav.	88° No.	5h 56m Hav.	89° No.
0	0	9.68354	0.48255	9.69132	0.49127
4	1	.68367	.48269	.69145	.49142
8	2	.68380	.48284	.69158	.49156
12	3	.68393	.48299	.69171	.49171
16	4	.68407	.48313	.69184	.49186
20	5	9.68420	0.48328	9.69197	0.49200
24	6	.68433	.48342	.69209	.49215
28	7	.68446	.48357	.69222	.49229
32	8	.68459	.48371	.69235	.49244
36	9	.68472	.48386	.69248	.49258
40	10	9.68485	0.48400	9.69261	0.49273
44	11	.68498	.48415	.69274	.49287
48	12	.68511	.48429	.69286	.49302
52	13	.68524	.48444	.69299	.49316
56	14	.68537	.48459	.69312	.49331
s	′	5h 53m	88°	5h 57m	89°
0	15	9.68550	0.48473	9.69325	0.49346
4	16	.68563	.48488	.69338	.49360
8	17	.68576	.48502	.69350	.49375
12	18	.68589	.48517	.69363	.49389
16	19	.68602	.48531	.69376	.49404
20	20	9.68615	0.48546	9.69389	0.49418
24	21	.68628	.48560	.69402	.49433
28	22	.68641	.48575	.69414	.49447
32	23	.68654	.48589	.69427	.49462
36	24	.68667	.48604	.69440	.49476
40	25	9.68680	0.48618	9.69453	0.49491
44	26	.68693	.48633	.69465	.49506
48	27	.68706	.48648	.69478	.49520
52	28	.68719	.48662	.69491	.49535
56	29	.68732	.48677	.69504	.49549
s	′	5h 54m	88°	5h 58m	89°
0	30	9.68745	0.48691	9.69516	0.49564
4	31	.68758	.48706	.69529	.49578
8	32	.68771	.48720	.69542	.49593
12	33	.68784	.48735	.69555	.49607
16	34	.68797	.48749	.69567	.49622
20	35	9.68810	0.48764	9.69580	0.49636
24	36	.68823	.48778	.69593	.49651
28	37	.68836	.48793	.69605	.49666
32	38	.68849	.48807	.69618	.49680
36	39	.68862	.48822	.69631	.49695
40	40	9.68875	0.48837	9.69644	0.49709
44	41	.68887	.48851	.69656	.49724
48	42	.68900	.48866	.69669	.49738
52	43	.68913	.48880	.69682	.49753
56	44	.68926	.48895	.69694	.49767
s	′	5h 55m	88°	5h 59m	89°
0	45	9.68939	0.48909	9.69707	0.49782
4	46	.68952	.48924	.69720	.49796
8	47	.68965	.48938	.69732	.49811
12	48	.68978	.48953	.69745	.49825
16	49	.68991	.48967	.69758	.49840
20	50	9.69004	0.48982	9.69770	0.49855
24	51	.69017	.48997	.69783	.49869
28	52	.69029	.49011	.69796	.49884
32	53	.69042	.49026	.69808	.49898
36	54	.69055	.49040	.69821	.49913
40	55	9.69068	0.49055	9.69834	0.49927
44	56	.69081	.49069	.69846	.49942
48	57	.69094	.49084	.69859	.49956
52	58	.69107	.49098	.69872	.49971
56	59	.69120	.49113	.69884	.49985
60	60	9.69132	0.49127	9.69897	0.50000

Note.—The No. column is omitted in the rest of this table, as the No. haversines are not needed beyond 6^h or **90°**.

s	6h 0m Hav.	6h 4m Hav.
0	9.69897	9.70648
4	.69910	.70661
8	.69922	.70673
12	.69935	.70686
16	.69948	.70698
20	9.69960	9.70710
24	.69973	.70723
28	.69985	.70735
32	.69998	.70748
36	.70011	.70760
40	9.70023	9.70772
44	.70036	.70785
48	.70048	.70797
52	.70061	.70809
56	.70074	.70822
s	6h 1m	6h 5m
0	9.70086	9.70834
4	.70099	.70847
8	.70111	.70859
12	.70124	.70871
16	.70136	.70884
20	9.70149	9.70896
24	.70161	.70908
28	.70174	.70921
32	.70187	.70933
36	.70199	.70945
40	9.70212	9.70958
44	.70224	.70970
48	.70237	.70982
52	.70249	.70995
56	.70262	.71007
s	6h 2m	6h 6m
0	9.70274	9.71019
4	.70287	.71032
8	.70299	.71044
12	.70312	.71056
16	.70324	.71068
20	9.70337	9.71081
24	.70349	.71093
28	.70362	.71105
32	.70374	.71118
36	.70387	.71130
40	9.70399	9.71142
44	.70412	.71154
48	.70424	.71167
52	.70437	.71179
56	.70449	.71191
s	6h 3m	6h 7m
0	9.70462	9.71203
4	.70474	.71216
8	.70487	.71228
12	.70499	.71240
16	.70512	.71252
20	9.70524	9.71265
24	.70537	.71277
28	.70549	.71289
32	.70561	.71301
36	.70574	.71314
40	9.70586	9.71326
44	.70599	.71338
48	.70611	.71350
52	.70624	.71362
56	.70636	.71375
60	9.70648	9.71387

s	6h 8m	6h 12m	6h 16m	6h 20m	6h 24m	6h 28m	6h 32m	6h 36m
	Hav.	Hav.	Hav.	Hav.	Hav.	Hav.	Hav.	Hav.
0	9.71387	9.72112	9.72825	9.73526	9.74215	9.74891	9.75556	9.76209
4	.71399	.72124	.72837	.73538	.74226	.74902	.75567	.76220
8	.71411	.72136	.72849	.73549	.74237	.74914	.75578	.76231
12	.71423	.72148	.72861	.73561	.74249	.74925	.75589	.76241
16	.71436	.72160	.72873	.73572	.74260	.74936	.75600	.76252
20	9.71448	9.72172	9.72884	9.73584	9.74272	9.74947	9.75611	9.76263
24	.71460	.72184	.72896	.73596	.74283	.74958	.75622	.76274
28	.71472	.72196	.72908	.73607	.74294	.74969	.75633	.76285
32	.71484	.72208	.72920	.73619	.74306	.74981	.75644	.76296
36	.71496	.72220	.72931	.73630	.74317	.74992	.75655	.76306
40	9.71509	9.72232	9.72943	9.73642	9.74328	9.75003	9.75666	9.76317
44	.71521	.72244	.72955	.73653	.74340	.75014	.75677	.76328
48	.71533	.72256	.72967	.73665	.74351	.75025	.75688	.76338
52	.71545	.72268	.72978	.73676	.74362	.75036	.75698	.76349
56	.71557	.72280	.72990	.73688	.74374	.75047	.75709	.76360

s	6h 9m	6h 13m	6h 17m	6h 21m	6h 25m	6h 29m	6h 33m	6h 37m
0	9.71569	9.72292	9.73002	9.73699	9.74385	9.75059	9.75720	9.76371
4	.71582	.72304	.73014	.73711	.74396	.75070	.75731	.76381
8	.71594	.72316	.73025	.73722	.74408	.75081	.75742	.76392
12	.71606	.72328	.73037	.73734	.74419	.75092	.75753	.76403
16	.71618	.72340	.73049	.73746	.74430	.75103	.75764	.76414
20	9.71630	9.72352	9.73060	9.73757	9.74442	9.75114	9.75775	9.76424
24	.71642	.72363	.73072	.73769	.74453	.75125	.75786	.76435
28	.71654	.72375	.73084	.73780	.74464	.75136	.75797	.76446
32	.71666	.72387	.73096	.73792	.74475	.75147	.75808	.76456
36	.71679	.72399	.73107	.73803	.74487	.75159	.75819	.76467
40	9.71691	9.72411	9.73119	9.73815	9.74498	9.75170	9.75830	9.76478
44	.71703	.72423	.73131	.73826	.74509	.75181	.75840	.76489
48	.71715	.72435	.73142	.73838	.74521	.75192	.75851	.76499
52	.71727	.72447	.73154	.73849	.74532	.75203	.75862	.76510
56	.71739	.72459	.73166	.73860	.74543	.75214	.75873	.76521

s	6h 10m	6h 14m	6h 18m	6h 22m	6h 26m	6h 30m	6h 34m	6h 38m
0	9.71751	9.72471	9.73177	9.73872	9.74554	9.75225	9.75884	9.76531
4	.71763	.72482	.73189	.73883	.74566	.75236	.75895	.76542
8	.71775	.72494	.73201	.73895	.74577	.75247	.75906	.76553
12	.71787	.72506	.73212	.73906	.74588	.75258	.75917	.76563
16	.71800	.72518	.73224	.73918	.74600	.75269	.75927	.76574
20	9.71812	9.72530	9.73236	9.73929	9.74611	9.75280	9.75938	9.76585
24	.71824	.72542	.73247	.73941	.74622	.75291	.75949	.76595
28	.71836	.72554	.73259	.73952	.74633	.75303	.75960	.76606
32	.71848	.72565	.73271	.73964	.74645	.75314	.75971	.76617
36	.71860	.72577	.73282	.73975	.74656	.75325	.75982	.76627
40	9.71872	9.72589	9.73294	9.73987	9.74667	9.75336	9.75993	9.76638
44	.71884	.72601	.73306	.73998	.74678	.75347	.76004	.76649
48	.71896	.72613	.73317	.74009	.74690	.75358	.76014	.76659
52	.71908	.72625	.73329	.74021	.74701	.75369	.76025	.76670
56	.71920	.72637	.73341	.74032	.74712	.75380	.76036	.76681

s	6h 11m	6h 15m	6h 19m	6h 23m	6h 27m	6h 31m	6h 35m	6h 39m
0	9.71932	9.72648	9.73352	9.74044	9.74723	9.75391	9.76047	9.76691
4	.71944	.72660	.73364	.74055	.74734	.75402	.76058	.76702
8	.71956	.72672	.73375	.74067	.74746	.75413	.76069	.76713
12	.71968	.72684	.73387	.74078	.74757	.75424	.76079	.76723
16	.71980	.72696	.73399	.74089	.74768	.75435	.76090	.76734
20	9.71992	9.72708	9.73410	9.74101	9.74779	9.75446	9.76101	9.76745
24	.72004	.72719	.73422	.74112	.74791	.75457	.76112	.76755
28	.72016	.72731	.73433	.74124	.74802	.75468	.76123	.76766
32	.72028	.72743	.73445	.74135	.74813	.75479	.76134	.76777
36	.72040	.72755	.73457	.74146	.74824	.75490	.76144	.76787
40	9.72052	9.72767	9.73468	9.74158	9.74835	9.75501	9.76155	9.76798
44	.72064	.72778	.73480	.74169	.74846	.75512	.76166	.76808
48	.72076	.72790	.73491	.74181	.74858	.75523	.76177	.76819
52	.72088	.72802	.73503	.74192	.74869	.75534	.76188	.76830
56	.72100	.72814	.73515	.74203	.74880	.75545	.76198	.76840
60	9.72112	9.72825	9.73526	9.74215	9.74891	9.75556	9.76209	9.76851

s	$6^h\,40^m$ Hav.	$6^h\,44^m$ Hav.	$6^h\,48^m$ Hav.	$6^h\,52^m$ Hav.	$6^h\,56^m$ Hav.	$7^h\,0^m$ Hav.	$7^h\,4^m$ Hav.	$7^h\,8^m$ Hav.
0	9.76851	9.77481	9.78101	9.78709	9.79306	9.79893	9.80470	9.81036
4	.76861	.77492	.78111	.78719	.79316	.79903	.80479	.81045
8	.76872	.77502	.78121	.78729	.79326	.79913	.80489	.81054
12	.76883	.77512	.78131	.78739	.79336	.79922	.80498	.81064
16	.76893	.77523	.78141	.78749	.79346	.79932	.80508	.81073
20	9.76904	9.77533	9.78152	9.78759	9.79356	9.79942	9.80517	9.81082
24	.76914	.77544	.78162	.78769	.79366	.79951	.80527	.81092
28	.76925	.77554	.78172	.78779	.79376	.79961	.80536	.81101
32	.76936	.77564	.78182	.78789	.79385	.79971	.80546	.81110
36	.76946	.77575	.78192	.78799	.79395	.79980	.80555	.81120
40	9.76957	9.77585	9.78203	9.78809	9.79405	9.79990	9.80565	9.88129
44	.76967	.77596	.78213	.78819	.79415	.80000	.80574	.81138
48	.76978	.77606	.78223	.78829	.79425	.80009	.80584	.81148
52	.76988	.77616	.78233	.78839	.79434	.80019	.80593	.81157
56	.76999	.77627	.78243	.78849	.79444	.80029	.80603	.81166
s	$6^h\,41^m$	$6^h\,45^m$	$6^h\,49^m$	$6^h\,53^m$	$6^h\,57^m$	$7^h\,1^m$	$7^h\,5^m$	$7^h\,9^m$
0	9.77009	9.77637	9.78254	9.78859	9.79454	9.80038	9.80612	9.81176
4	.77020	.77647	.78264	.78869	.79464	.80048	.80622	.81185
8	.77031	.77658	.78274	.78879	.79474	.80058	.80631	.81194
12	.77041	.77668	.78284	.78889	.79484	.80067	.80641	.81204
16	.77052	.77679	.78294	.78899	.79493	.80077	.80650	.81213
20	9.77062	9.77689	9.78305	9.78909	9.79503	9.80087	9.80660	9.81222
24	.77073	.77699	.78315	.78919	.79513	.80096	.80669	.81231
28	.77083	.77710	.78325	.78929	.79523	.80106	.80678	.81241
32	.77094	.77720	.78335	.78939	.79533	.80116	.80688	.81250
36	.77104	.77730	.78345	.78949	.79542	.80125	.80697	.81259
40	9.77115	9.77741	9.78355	9.78959	9.79552	9.80135	9.80707	9.81269
44	.77125	.77751	.78365	.78969	.79562	.80144	.80716	.81278
48	.77136	.77761	.78376	.78979	.79572	.80154	.80726	.81287
52	.77146	.77772	.78386	.78989	.79582	.80164	.80735	.81296
56	.77157	.77782	.78396	.78999	.79591	.80173	.80745	.81306
s	$6^h\,42^m$	$6^h\,46^m$	$6^h\,50^m$	$6^h\,54^m$	$6^h\,58^m$	$7^h\,2^m$	$7^h\,6^m$	$7^h\,10^m$
0	9.77167	9.77792	9.78406	9.79009	9.79601	9.80183	9.80754	9.81315
4	.77178	.77803	.78416	.79019	.79611	.80192	.80763	.81324
8	.77188	.77813	.78426	.79029	.79621	.80202	.80773	.81333
12	.77199	.77823	.78436	.79039	.79631	.80212	.80782	.81343
16	.77209	.77834	.78447	.79049	.79640	.80221	.80792	.81352
20	9.77220	9.77844	9.78457	9.79059	9.79650	9.80231	9.80801	9.81361
24	.77230	.77854	.78467	.79069	.79660	.80240	.80811	.81370
28	.77241	.77864	.78477	.79079	.79670	.80250	.80820	.81380
32	.77251	.77875	.78487	.79089	.79679	.80260	.80829	.81389
36	.77262	.77885	.78497	.79099	.79689	.80269	.80839	.81398
40	9.77272	9.77895	9.78507	9.79108	9.79699	9.80279	9.80848	9.81407
44	.77283	.77906	.78517	.79118	.79709	.80288	.80858	.81417
48	.77293	.77916	.78528	.79128	.79718	.80298	.80867	.81426
52	.77304	.77926	.78538	.79138	.79728	.80307	.80876	.81435
56	.77314	.77936	.78548	.79148	.79738	.80317	.80886	.81444
s	$6^h\,43^m$	$6^h\,47^m$	$6^h\,51^m$	$6^h\,55^m$	$6^h\,59^m$	$7^h\,3^m$	$7^h\,7^m$	$7^h\,11^m$
0	9.77325	9.77947	9.78558	9.79158	9.79748	9.80327	9.80895	9.81454
4	.77335	.77957	.78568	.79168	.79757	.80336	.80905	.81463
8	.77346	.77967	.78578	.79178	.79767	.80346	.80914	.81472
12	.77356	.77978	.78588	.79188	.79777	.80355	.80923	.81481
16	.77366	.77988	.78598	.79198	.79787	.80365	.80933	.81490
20	9.77377	9.77998	9.78608	9.79208	9.79796	9.80374	9.80942	9.81500
24	.77387	.78008	.78618	.79217	.79806	.80384	.80952	.81509
28	.77398	.78019	.78628	.79227	.79816	.80393	.80961	.81518
32	.77408	.78029	.78638	.79237	.79825	.80403	.80970	.81527
36	.77419	.78039	.78649	.79247	.79835	.80413	.80980	.81536
40	9.77429	9.78049	9.78659	9.79257	9.79845	9.80422	9.80989	9.81546
44	.77440	.78060	.78669	.79267	.79855	.80432	.80998	.81555
48	.77450	.78070	.78679	.79277	.79864	.80441	.81008	.81564
52	.77460	.78080	.78689	.79287	.79874	.80451	.81017	.81573
56	.77471	.78090	.78699	.79297	.79884	.80460	.81026	.81582
60	9.77481	9.78101	9.78709	9.79306	9.79893	9.80470	9.81036	9.81592

s	$7^h\ 12^m$	$7^h\ 16^m$	$7^h\ 20^m$	$7^h\ 24^m$	$7^h\ 28^m$	$7^h\ 32^m$	$7^h\ 36^m$	$7^h\ 40^m$
	Hav.	**Hav.**	**Hav.**	**Hav.**	**Hav.**	**Hav.**	**Hav.**	**Hav.**
0	9.81592	9.82137	9.82673	9.83199	9.83715	9.84221	9.84718	9.85206
4	.81601	.82146	.82682	.83207	.83723	.84230	.84726	.85214
8	.81610	.82155	.82691	.83216	.83732	.84238	.84735	.85222
12	.81619	.82164	.82699	.83225	.83740	.84246	.84743	.85230
16	.81628	.82173	.82708	.83233	.83749	.84255	.84751	.85238
20	9.81637	9.82182	9.82717	9.83242	9.83757	9.84263	9.84759	9.85246
24	.81647	.82191	.82726	.83251	.83766	.84271	.84767	.85254
28	.81656	.82200	.82735	.83259	.83774	.84280	.84776	.85262
32	.81665	.82209	.82744	.83268	.83783	.84288	.84784	.85270
36	.81674	.82218	.82752	.83277	.83791	.84296	.84792	.85278
40	9.81683	9.82227	9.82761	9.83285	9.83800	9.84305	9.84800	9.85286
44	.81692	.82236	.82770	.83294	.83808	.84313	.84808	.85294
48	.81701	.82245	.82779	.83303	.83817	.84321	.84817	.85302
52	.81711	.82254	.82788	.83311	.83825	.84330	.84825	.85310
56	.81720	.82263	.82796	.83320	.83834	.84338	.84833	.85318

s	$7^h\ 13^m$	$7^h\ 17^m$	$7^h\ 21^m$	$7^h\ 25^m$	$7^h\ 29^m$	$7^h\ 33^m$	$7^h\ 37^m$	$7^h\ 41^m$
0	9.81729	9.82272	9.82805	9.83329	9.83842	9.84346	9.84841	9.85326
4	.81738	.82281	.82814	.83337	.83851	.84355	.84849	.85334
8	.81747	.82290	.82823	.83346	.83859	.84363	.84857	.85342
12	.81756	.82299	.82832	.83355	.83868	.84371	.84866	.85350
16	.81765	.82308	.82840	.83363	.83876	.84380	.84874	.85358
20	9.81775	9.82317	9.82849	9.83372	9.83885	9.84388	9.84882	9.85366
24	.81784	.82326	.82858	.83380	.83893	.84396	.84890	.85374
28	.81793	.82335	.82867	.83389	.83902	.84405	.84898	.85382
32	.81802	.82344	.82876	.83398	.83910	.84413	.84906	.85390
36	.81811	.82353	.82884	.83406	.83919	.84421	.84914	.85398
40	9.81820	9.82362	9.82893	9.83415	9.83927	9.84430	9.84923	9.85406
44	.81829	.82371	.82902	.83424	.83935	.84438	.84931	.85414
48	.81838	.82380	.82911	.83432	.83944	.84446	.84939	.85422
52	.81847	.82388	.82920	.83441	.83952	.84454	.84947	.85430
56	.81857	.82397	.82928	.83449	.83961	.84463	.84955	.85438

s	$7^h\ 14^m$	$7^h\ 18^m$	$7^h\ 22^m$	$7^h\ 26^m$	$7^h\ 30^m$	$7^h\ 34^m$	$7^h\ 38^m$	$7^h\ 42^m$
0	9.81866	9.82406	9.82937	9.83458	9.83969	9.84471	9.84963	9.85446
4	.81875	.82415	.82946	.83467	.83978	.84479	.84971	.85454
8	.81884	.82424	.82955	.83475	.83986	.84488	.84979	.85462
12	.81893	.82433	.82963	.83484	.83995	.84496	.84988	.85470
16	.81902	.82442	.82972	.83492	.84003	.84504	.84996	.85478
20	9.81911	9.82451	9.82981	9.83501	9.84011	9.84512	9.85004	9.85486
24	.81920	.82460	.82990	.83510	.84020	.84521	.85012	.85494
28	.81929	.82469	.82998	.83518	.84028	.84529	.85020	.85502
32	.81938	.82478	.83007	.83527	.84037	.84537	.85028	.85510
36	.81947	.82487	.83016	.83535	.84045	.84545	.85036	.85518
40	9.81956	9.82495	9.83025	9.83544	9.84054	9.84554	9.85044	9.85526
44	.81965	.82504	.83033	.83552	.84062	.84562	.85052	.85534
48	.81975	.82513	.83042	.83561	.84070	.84570	.85061	.85542
52	.81984	.82522	.83051	.83570	.84079	.84578	.85069	.85550
56	.81993	.82531	.83059	.83578	.84087	.84587	.85077	.85557

s	$7^h\ 15^m$	$7^h\ 19^m$	$7^h\ 23^m$	$7^h\ 27^m$	$7^h\ 31^m$	$7^h\ 35^m$	$7^h\ 39^m$	$7^h\ 43^m$
0	9.82002	9.82540	9.83068	9.83587	9.84096	9.84595	9.85085	9.85565
4	.82011	.82549	.83077	.83595	.84104	.84603	.85093	.85573
8	.82020	.82558	.83086	.83604	.84112	.84611	.85101	.85581
12	.82029	.82567	.83094	.83612	.84121	.84620	.85109	.85589
16	.82038	.82575	.83103	.83621	.84129	.84628	.85117	.85597
20	9.82047	9.82584	9.83112	9.83630	9.84138	9.84636	9.85125	9.85605
24	.82056	.82593	.83120	.83638	.84146	.84644	.85133	.85613
28	.82065	.82602	.83129	.83647	.84154	.84653	.85141	.85621
32	.82074	.82611	.83138	.83655	.84163	.84661	.85149	.85629
36	.82083	.82620	.83147	.83664	.84171	.84669	.85158	.85637
40	9.82092	9.82629	9.83155	9.83672	9.84179	9.84677	9.85166	9.85645
44	.82101	.82638	.83164	.83681	.84188	.84685	.85174	.85653
48	.82110	.82646	.83173	.83689	.84196	.84694	.85182	.85660
52	.82119	.82655	.83181	.83698	.84205	.84702	.85190	.85668
56	.82128	.82664	.83190	.83706	.84213	.84710	.85198	.85676
60	9.82137	9.82673	9.83199	9.83715	9.84221	9.84718	9.85206	9.85684

s	$7^h 44^m$	$7^h 48^m$	$7^h 52^m$	$7^h 56^m$	$8^h 0^m$	$8^h 4^m$	$8^h 8^m$	$8^h 12^m$
	Hav.	**Hav.**	**Hav.**	**Hav.**	**Hav.**	**Hav.**	**Hav.**	**Hav.**
0	9.85684	9.86153	9.86613	9.87064	9.87506	9.87939	9.88364	9.88780
4	.85692	.86161	.86621	.87072	.87513	.87947	.88371	.88787
8	.85700	.86169	.86628	.87079	.87521	.87954	.88378	.88793
12	.85708	.86176	.86636	.87086	.87528	.87961	.88385	.88800
16	.85716	.86184	.86643	.87094	.87535	.87968	.88392	.88807
20	9.85724	9.86192	9.86651	9.87101	9.87543	9.87975	9.88399	9.88814
24	.85731	.86200	.86659	.87109	.87550	.87982	.88406	.88821
28	.85739	.86207	.86666	.87116	.87557	.87989	.88413	.88828
32	.85747	.86215	.86674	.87124	.87564	.87996	.88420	.88835
36	.85755	.86223	.86681	.87131	.87572	.88004	.88427	.88841
40	9.85763	9.86230	9.86689	9.87138	9.87579	9.88011	9.88434	9.88848
44	.85771	.86238	.86696	.87146	.87586	.88018	.88441	.88855
48	.85779	.86246	.86704	.87153	.87593	.88025	.88448	.88862
52	.85787	.86254	.86712	.87161	.87601	.88032	.88455	.88869
56	.85794	.86261	.86719	.87168	.87608	.88039	.88462	.88876
s	$7^h 45^m$	$7^h 49^m$	$7^h 53^m$	$7^h 57^m$	$8^h 1^m$	$8^h 5^m$	$8^h 9^m$	$8^h 13^m$
0	9.85802	9.86269	9.86727	9.87175	9.87615	9.88046	9.88469	9.88882
4	.85810	.86277	.86734	.87183	.87623	.88053	.88476	.88889
8	.85818	.86284	.86742	.87190	.87630	.88061	.88483	.88896
12	.85826	.86292	.86749	.87198	.87637	.88068	.88490	.88903
16	.85834	.86300	.86757	.87205	.87644	.88075	.88496	.88910
20	9.85841	9.86307	9.86764	9.87212	9.87652	9.88082	9.88503	9.88916
24	.85849	.86315	.86772	.87220	.87659	.88089	.88510	.88923
28	.85857	.86323	.86780	.87227	.87666	.88096	.88517	.88930
32	.85865	.86331	.86787	.87235	.87673	.88103	.88524	.88937
36	.85873	.86338	.86795	.87242	.87680	.88110	.88531	.88944
40	9.85881	9.86346	9.86802	9.87249	9.87688	9.88117	9.88528	9.88950
44	.85888	.86354	.86810	.87257	.87695	.88124	.88545	.88957
48	.85896	.86361	.86817	.87264	.87702	.88131	.88552	.88964
52	.85904	.86369	.86825	.87271	.87709	.88139	.88559	.88971
56	.85912	.86377	.86832	.87279	.87717	.88146	.88566	.88978
s	$7^h 46^m$	$7^h 50^m$	$7^h 54^m$	$7^h 58^m$	$8^h 2^m$	$8^h 6^m$	$8^h 10^m$	$8^h 14^m$
0	9.85920	9.86384	9.86840	9.87286	9.87724	9.88153	9.88573	9.88984
4	.85928	.86392	.86847	.87294	.87731	.88160	.88580	.88991
8	.85935	.86400	.86855	.87301	.87738	.88167	.88587	.88998
12	.85943	.86407	.86862	.87308	.87745	.88174	.88594	.89005
16	.85951	.86415	.86870	.87316	.87753	.88181	.88600	.89012
20	9.85959	9.86423	9.86877	9.87323	9.87760	9.88188	9.88607	9.89018
24	.85967	.86430	.86885	.87330	.87767	.88195	.88614	.89025
28	.85974	.86438	.86892	.87338	.87774	.88202	.88621	.89032
32	.85982	.86446	.86900	.87345	.87782	.88209	.88628	.89039
36	.85990	.86453	.86907	.87352	.87789	.88216	.88635	.89045
40	9.85998	9.86461	9.86915	9.87360	9.87796	9.88223	9.88642	9.89052
44	.86006	.86468	.86922	.87367	.87803	.88230	.88649	.89059
48	.86013	.86476	.86930	.87374	.87810	.88237	.88656	.89066
52	.86021	.86484	.86937	.87382	.87818	.88244	.88663	.89072
56	.86029	.86491	.86945	.87389	.87825	.88252	.88670	.89079
s	$7^h 47^m$	$7^h 51^m$	$7^h 55^m$	$7^h 59^m$	$8^h 3^m$	$8^h 7^m$	$8^h 11^m$	$8^h 15^m$
0	9.86037	9.86499	9.86952	9.87396	9.87832	9.88259	9.88677	9.89086
4	.86045	.86507	.86960	.87404	.87839	.88266	.88683	.89093
8	.86052	.86514	.86967	.87411	.87846	.88273	.88690	.89099
12	.86060	.86522	.86975	.87418	.87853	.88280	.88697	.89106
16	.86068	.86529	.86982	.87426	.87861	.88287	.88704	.89113
20	9.86076	9.86537	9.86990	9.87433	9.87868	9.88294	9.88711	9.89120
24	.86083	.86545	.86997	.87440	.87875	.88301	.88718	.89126
28	.86091	.86552	.87004	.87448	.87882	.88308	.88725	.89133
32	.86099	.86560	.87012	.87455	.87889	.88315	.88732	.89140
36	.86107	.86568	.87019	.87462	.87896	.88322	.88739	.89147
40	9.86114	9.86575	9.87027	9.87470	9.87904	9.88329	9.88745	9.89153
44	.86122	.86583	.87034	.87477	.87911	.88336	.88752	.89160
48	.86130	.86590	.87042	.87484	.87918	.88343	.88759	.89167
52	.86138	.86598	.87049	.87492	.87925	.88350	.88766	.89174
56	.86145	.86606	.87057	.87499	.87932	.88357	.88773	.89180
60	9.86153	9.86613	9.87064	9.87506	9.87939	9.88364	9.88780	9.89187

s	$8^h\,16^m$	$8^h\,20^m$	$8^h\,24^m$	$8^h\,28^m$	$8^h\,32^m$	$8^h\,36^m$	$8^h\,40^m$	$8^h\,44^m$
	Hav.	**Hav.**	**Hav.**	**Hav.**	**Hav.**	**Hav.**	**Hav.**	**Hav.**
0	9.89187	9.89586	9.89976	9.90358	9.90732	9.91098	9.91455	9.91805
4	.89194	.89592	.89983	.90365	.90738	.91104	.91461	.91810
8	.89200	.89599	.89989	.90371	.90744	.91110	.91467	.91816
12	.89207	.89606	.89995	.90377	.90751	.91116	.91473	.91822
16	.89214	.89612	.90002	.90383	.90757	.91122	.91479	.91828
20	9.89221	9.89619	9.90008	9.90390	9.90763	9.91128	9.91485	9.91833
24	.89227	.89625	.90015	.90396	.90769	.91134	.91490	.91839
28	.89234	.89632	.90021	.90402	.90775	.91140	.91496	.91845
32	.89241	.89638	.90028	.90409	.90781	.91146	.91502	.91851
36	.89247	.89645	.90034	.90415	.90787	.91152	.91508	.91856
40	9.89254	9.89651	9.90040	9.90421	9.90794	9.91158	9.91514	9.91862
44	.89261	.89658	.90047	.90428	.90800	.91164	.91520	.91868
48	.89267	.89665	.90053	.90434	.90806	.91170	.91526	.91874
52	.89274	.89671	.90060	.90440	.90812	.91176	.91532	.91879
56	.89281	.89678	.90066	.90446	.90818	.91182	.91537	.91885
s	$8^h\,17^m$	$8^h\,21^m$	$8^h\,25^m$	$8^h\,29^m$	$8^h\,33^m$	$8^h\,37^m$	$8^h\,41^m$	$8^h\,45^m$
0	9.89287	9.89684	9.90072	9.90452	9.90824	9.91188	9.91543	9.91891
4	.89294	.89691	.90079	.90459	.90830	.91194	.91549	.91896
8	.89301	.89697	.90085	.90465	.90836	.91200	.91555	.91902
12	.89308	.89704	.90092	.90471	.90843	.91206	.91561	.91908
16	.89314	.89710	.90098	.90478	.90849	.91212	.91567	.91914
20	9.89321	9.89717	9.90104	9.90484	9.90855	9.91218	9.91573	9.91919
24	.89328	.89723	.90111	.90490	.90861	.91224	.91578	.91925
28	.89334	.89730	.90117	.90496	.90867	.91230	.91584	.91931
32	.89341	.89736	.90124	.90503	.90873	.91236	.91590	.91936
36	.89348	.89743	.90130	.90509	.90879	.91242	.91596	.91942
40	9.89354	9.89749	9.90136	9.90515	9.90885	9.91248	9.91602	9.91948
44	.89361	.89756	.90143	.90521	.90892	.91254	.91608	.91954
48	.89368	.89763	.90149	.90527	.90898	.91260	.91613	.91959
52	.89374	.89769	.90156	.90534	.90904	.91265	.91619	.91965
56	.89381	.89776	.90162	.90540	.90910	.91271	.91625	.91971
s	$8^h\,18^m$	$8^h\,22^m$	$8^h\,26^m$	$8^h\,30^m$	$8^h\,34^m$	$8^h\,38^m$	$8^h\,42^m$	$8^h\,46^m$
0	9.89387	9.89782	9.90168	9.90546	9.90916	9.91277	9.91631	9.91976
4	.89394	.89789	.90175	.90552	.90922	.91283	.91637	.91982
8	.89400	.89795	.90181	.90559	.90928	.91289	.91643	.91988
12	.89407	.89802	.90187	.90565	.90934	.91295	.91648	.91993
16	.89414	.89808	.90194	.90571	.90940	.91301	.91654	.91999
20	9.89421	9.89815	9.90200	9.90577	9.90946	9.91307	9.91660	9.92005
24	.89427	.89821	.90206	.90584	.90952	.91313	.91666	.92010
28	.89434	.89828	.90213	.90590	.90958	.91319	.91672	.92016
32	.89441	.89834	.90219	.90596	.90965	.91325	.91677	.92022
36	.89447	.89840	.90225	.90602	.90971	.91331	.91683	.92027
40	9.89454	9.89847	9.90232	9.90608	9.90977	9.91337	9.91689	9.92033
44	.89460	.89853	.90238	.90615	.90983	.91343	.91695	.92039
48	.89467	.89860	.90244	.90621	.90989	.91349	.91701	.92044
52	.89474	.89866	.90251	.90627	.90995	.91355	.91706	.92050
56	.89480	.89873	.90257	.90633	.91001	.91361	.91712	.92056
s	$8^h\,19^m$	$8^h\,23^m$	$8^h\,27^m$	$8^h\,31^m$	$8^h\,35^m$	$8^h\,39^m$	$8^h\,43^m$	$8^h\,47^m$
0	9.89487	9.89879	9.90264	9.90639	9.91007	9.91367	9.91718	9.92061
4	.89493	.89886	.90270	.90646	.91013	.91372	.91724	.92067
8	.89500	.89892	.90276	.90652	.91019	.91378	.91730	.92073
12	.89507	.89899	.90282	.90658	.91025	.91384	.91735	.92078
16	.89513	.89905	.90289	.90664	.91031	.91390	.91741	.92084
20	9.89520	9.89912	9.90295	9.90670	9.91037	9.91396	9.91747	9.92090
24	.89527	.89918	.90301	.90676	.91043	.91402	.91753	.92095
28	.89533	.89925	.90308	.90683	.91049	.91408	.91758	.92101
32	.89540	.89931	.90314	.90689	.91055	.91414	.91764	.92107
36	.89546	.89938	.90320	.90695	.91061	.91420	.91770	.92112
40	9.89553	9.89944	9.90327	9.90701	9.01067	9.91426	9.91776	9.92118
44	.89559	.89950	.90333	.90707	.91074	.91432	.91782	.92124
48	.89566	.89957	.90339	.90714	.91080	.91437	.91787	.92129
52	.89573	.89963	.90346	.90720	.91086	.91443	.91793	.92135
56	.89579	.89970	.90352	.90726	.91092	.91449	.91799	.92140
60	9.89586	9.89976	9.90358	9.90732	9.19098	9.91455	9.91805	9.92146

Table 10. Haversine Table

s	$8^h\ 48^m$	$8^h\ 52^m$	$8^h\ 56^m$	$9^h\ 0^m$	$9^h\ 4^m$	$9^h\ 8^m$	$9^h\ 12^m$	$9^h\ 16^m$
	Hav.	Hav.	Hav.	Hav.	Hav.	Hav.	Hav.	Hav.
0	9.92146	9.92480	9.92805	9.93123	9.93433	9.93736	9.94030	9.94318
4	.92152	.92485	.92811	.93128	.93438	.93741	.94035	.94322
8	.92157	.92491	.92816	.93134	.93443	.93746	.94040	.94327
12	.92163	.92496	.92821	.93139	.93448	.93751	.94045	.94332
16	.92169	.92502	.92827	.93144	.93454	.93755	.94050	.94336
20	9.92174	9.92507	9.92832	9.93149	9.93459	9.93760	9.94055	9.94341
24	.92180	.92512	.92837	.93154	.93464	.93765	.94059	.94346
28	.92185	.92518	.92843	.93160	.93469	.93770	.94064	.94351
32	.92191	.92523	.92848	.93165	.93474	.93775	.94069	.94355
36	.92197	.92529	.92853	.93170	.93479	.93780	.94074	.94360
40	9.92202	9.92534	9.92859	9.93175	9.93484	9.93785	9.94079	9.94365
44	.92208	.92540	.92864	.93181	.93489	.93790	.94084	.94369
48	.92213	.92545	.92869	.93186	.93494	.93795	.94088	.94374
52	.92219	.92551	.92875	.93191	.93499	.93800	.94093	.94379
56	.92225	.92556	.92880	.93196	.93504	.93805	.94098	.94383
s	$8^h\ 49^m$	$8^h\ 53^m$	$8^h\ 57^m$	$9^h\ 1^m$	$9^h\ 5^m$	$9^h\ 9^m$	$9^h\ 13^m$	$9^h\ 17^m$
0	9.92230	9.92562	9.92885	9.93201	9.93509	9.93810	9.94103	9.94388
4	.92236	.92567	.92891	.93207	.93515	.93815	.94108	.94393
8	.92241	.92573	.92896	.93212	.93520	.93820	.94112	.94398
12	.92247	.92578	.92901	.93217	.93525	.93825	.94117	.94402
16	.92253	.92584	.92907	.93222	.93530	.93830	.94122	.94407
20	9.92258	9.92589	9.92912	9.93227	9.93535	9.93835	9.94127	9.94412
24	.92264	.92594	.92917	.93232	.93540	.93840	.94132	.94416
28	.92269	.92600	.92923	.93238	.93545	.93845	.94137	.94421
32	.92275	.92605	.92928	.93243	.93550	.93849	.94141	.94426
36	.92280	.92611	.92933	.93248	.93555	.93854	.94146	.94430
40	9.92286	9.92616	9.92939	9.93253	9.93560	9.93859	9.94151	9.94435
44	.92292	.92622	.92944	.93258	.93565	.93864	.94156	.94440
48	.92297	.92627	.92949	.93264	.93570	.93869	.94161	.94444
52	.92303	.92633	.92955	.93269	.93575	.93874	.94165	.94449
56	.92308	.92638	.92960	.93274	.93580	.93879	.94170	.94454
s	$8^h\ 50^m$	$8^h\ 54^m$	$8^h\ 58^m$	$9^h\ 2^m$	$9^h\ 6^m$	$9^h\ 10^m$	$9^h\ 14^m$	$9^h\ 18^m$
0	9.92314	9.92643	9.92965	9.93279	9.93585	9.93884	9.94175	9.94458
4	.92319	.92649	.92970	.93284	.93590	.93889	.94180	.94463
3	.92325	.92654	.92975	.93289	.93595	.93894	.94184	.94468
12	.92330	.92660	.92981	.93295	.93600	.93899	.94189	.94472
16	.92336	.92665	.92986	.93300	.93605	.93904	.94194	.94477
20	9.92342	9.92670	9.92992	9.93305	9.93611	9.93908	9.94199	9.94482
24	.92347	.92676	.92997	.93310	.93616	.93913	.94204	.94486
28	.92353	.92681	.93002	.93315	.93621	.93918	.94208	.94491
32	.92358	.92687	.93007	.93320	.93626	.93923	.94213	.94496
36	.92364	.92692	.93013	.93326	.93631	.93928	.94218	.94500
40	9.92369	9.92698	9.93018	9.93331	9.93636	9.93933	9.94223	9.94505
44	.92375	.92703	.93023	.93336	.93641	.93938	.94227	.94509
48	.92380	.92708	.93029	.93341	.93646	.93943	.94232	.94514
52	.92386	.92714	.93034	.93346	.93651	.93948	.94237	.94519
56	.92391	.92719	.93039	.93351	.93656	.93952	.94242	.94523
s	$8^h\ 51^m$	$8^h\ 55^m$	$8^h\ 59^m$	$9^h\ 3^m$	$9^h\ 7^m$	$9^h\ 11^m$	$9^h\ 15^m$	$9^h\ 19^m$
0	9.92397	9.92725	9.93044	9.93356	9.93661	9.93957	9.94246	9.94528
4	.92402	.92730	.93050	.93362	.93666	.93962	.94251	.94533
8	.92408	.92735	.93055	.93367	.93671	.93967	.94256	.94537
12	.92413	.92741	.93060	.93372	.93676	.93972	.94261	.94542
16	.92419	.92746	.93065	.93377	.93681	.93977	.94265	.94546
20	9.92425	9.92751	9.93071	9.93382	9.93686	9.93982	9.94270	9.94551
24	.92430	.92757	.93076	.93387	.93691	.93987	.94275	.94556
28	.92436	.92762	.93081	.93392	.93696	.93991	.94280	.94560
32	.92441	.92768	.93086	.93397	.93701	.93996	.94284	.94565
36	.92447	.92773	.93092	.93403	.93706	.94001	.94289	.94570
40	9.92452	9.92778	9.93097	9.93408	9.93711	9.94006	9.94294	9.94574
44	.92458	.92784	.93102	.93413	.93716	.94011	.94299	.94579
48	.92463	.92789	.93107	.93418	.93721	.94016	.94303	.94583
52	.92469	.92794	.93113	.93423	.93726	.94021	.94308	.94588
56	.92474	.92800	.93118	.93428	.93731	.94026	.94313	.94593
60	9.92480	9.92805	9.93123	9.93433	9.93736	9.94030	9.94318	9.94597

s	$9^h 20^m$	$9^h 24^m$	$9^h 28^m$	$9^h 32^m$	$9^h 36^m$	$9^h 40^m$	$9^h 44^m$	$9^h 48^m$
	Hav.	Hav.	Hav.	Hav.	Hav.	Hav.	Hav.	Hav.
0	9.94597	9.94869	9.95134	9.95391	9.95641	9.95884	9.96119	9.96347
4	.94602	.94874	.95138	.95396	.95645	.95888	.96123	.96351
8	.94606	.94878	.95143	.95400	.95649	.95892	.96127	.96355
12	.94611	.94883	.95147	.95404	.95654	.95896	.96131	.96359
16	.94616	.94887	.95151	.95408	.95658	.95900	.96135	.96362
20	9.94620	9.94892	9.95156	9.95412	9.95662	9.95904	9.96139	9.96366
24	.94625	.94896	.95160	.95417	.95666	.95908	.96142	.96370
28	.94629	.94901	.95164	.95421	.95670	.95912	.96146	.96374
32	.94634	.94905	.95169	.95425	.95674	.95916	.96150	.96377
36	.94638	.94909	.95173	.95429	.95678	.95920	.96154	.96381
40	9.94643	9.94914	9.95177	9.95433	9.95682	9.95924	9.96158	9.96385
44	.94648	.94918	.95182	.95438	.95686	.95928	.96162	.96388
48	.94652	.94923	.95186	.95442	.95690	.95932	.96165	.96392
52	.94657	.94927	.95190	.95446	.95694	.95936	.96169	.96396
56	.94661	.94932	.95195	.95450	.95699	.95939	.96173	.96400
s	$9^h 21^m$	$9^h 25^m$	$9^h 29^m$	$9^h 33^m$	$9^h 37^m$	$9^h 41^m$	$9^h 45^m$	$9^h 49^m$
0	9.94666	9.94936	9.95199	9.95454	9.95703	9.95943	9.96177	9.96403
4	.94670	.94941	.95203	.95459	.95707	.95947	.96181	.96407
8	.94675	.94945	.95208	.95463	.95711	.95951	.96185	.96411
12	.94680	.94950	.95212	.95467	.95715	.95955	.96188	.96412
16	.94684	.94954	.95216	.95471	.95719	.95959	.96192	.96418
20	9.94689	9.94958	9.95221	9.95475	9.95723	9.95963	9.96196	9.96422
24	.94693	.94963	.95225	.95480	.95727	.95967	.96200	.96426
28	.94698	.94967	.95229	.95484	.95731	.95971	.96204	.96429
32	.94702	.94972	.95234	.95488	.95735	.95975	.96208	.96433
36	.94707	.94976	.95238	.95492	.95739	.95979	.96211	.96437
40	9.94711	9.94981	9.95242	9.95496	9.95743	9.95983	9.96215	9.96440
44	.94716	.94985	.95246	.95501	.95747	.95987	.96219	.96444
48	.94721	.94989	.95251	.95505	.95751	.95991	.96223	.96448
52	.94725	.94994	.95255	.95509	.95755	.95995	.96227	.96451
56	.94730	.94998	.95259	.95513	.95759	.95999	.96230	.96455
s	$9^h 22^m$	$9^h 26^m$	$9^h 30^m$	$9^h 34^m$	$9^h 38^m$	$9^h 42^m$	$9^h 46^m$	$9^h 50^m$
0	9.94734	9.95003	9.95264	9.95517	9.95763	9.96002	9.96234	9.96459
4	.94739	.95007	.95268	.95521	.95768	.96006	.96238	.96462
8	.94743	.95011	.95272	.95526	.95772	.96010	.96242	.96466
12	.94748	.95016	.95276	.95530	.95776	.96014	.96246	.96470
16	.94752	.95020	.95281	.95534	.95780	.96018	.96249	.96473
20	9.94757	9.95025	9.95285	9.95538	9.95784	9.96022	9.96253	9.96477
24	.94761	.95029	.95289	.95542	.95788	.96026	.96257	.96481
28	.94766	.95033	.95294	.95546	.95792	.96030	.96261	.96484
32	.94770	.95038	.95298	.95550	.95796	.96034	.96265	.96488
36	.94774	.95042	.95302	.95555	.95800	.96038	.96268	.96492
40	9.94779	9.95047	9.95306	9.95559	9.95804	9.96042	9.96272	9.96495
44	.94784	.95051	.95311	.95563	.95808	.96046	.96276	.96499
48	.94788	.95055	.95315	.95567	.95812	.96049	.96280	.96503
52	.94793	.95060	.95319	.95571	.95816	.96053	.96283	.96506
56	.94797	.95064	.95323	.95575	.95820	.96057	.96287	.96510
s	$9^h 23^m$	$9^h 27^m$	$9^h 31^m$	$9^h 35^m$	$9^h 39^m$	$9^h 43^m$	$9^h 47^m$	$9^h 51^m$
0	9.94802	9.95069	9.95328	9.95579	9.95824	9.96061	9.96291	9.96514
4	.94806	.95073	.95332	.95584	.95828	.96065	.96295	.96517
8	.94811	.95077	.95336	.95588	.95832	.96069	.96299	.96521
12	.94815	.95082	.95340	.95592	.95836	.96073	.96302	.96525
16	.94820	.95086	.95345	.95596	.95840	.96077	.96306	.96528
20	9.94824	9.95090	9.95349	9.95600	9.95844	9.96081	9.96310	9.96532
24	.94829	.95095	.95353	.95604	.95848	.96084	.96314	.96536
28	.94833	.95099	.95357	.95608	.95852	.96088	.96317	.96539
32	.94838	.95104	.95362	.95613	.95856	.96092	.96321	.96543
36	.94842	.95108	.95366	.95617	.95860	.96096	.96325	.96547
40	9.94847	9.95112	9.95370	9.95621	9.95864	9.96100	9.96329	9.96550
44	.94851	.95117	.95374	.95625	.95868	.96104	.96332	.96554
48	.94856	.95121	.95379	.95629	.95872	.96108	.96336	.96557
52	.94860	.95125	.95383	.95633	.95876	.96112	.96340	.96561
56	.94865	.95130	.95387	.95637	.95880	.96115	.96344	.96565
60	9.94869	9.95134	9.95391	9.95641	9.95884	9.96119	9.96347	9.96568

s	$9^h 52^m$	$9^h 56^m$	$10^h 0^m$	$10^h 4^m$	$10^h 8^m$	$10^h 12^m$	$10^h 16^m$	$10^h 20^m$
	Hav.	**Hav.**	**Hav.**	**Hav.**	**Hav.**	**Hav.**	**Hav.**	**Hav.**
0	9.96568	9.96782	9.96989	9.97188	9.97381	9.97566	9.97745	9.97916
4	.96572	.96786	.96992	.97192	.97384	.97569	.97748	.97919
8	.96576	.96789	.96996	.97195	.97387	.97572	.97751	.97922
12	.96579	.96793	.96999	.97198	.97390	.97575	.97754	.97925
16	.96583	.96796	.97002	.97201	.97393	.97578	.97756	.97927
20	9.96586	9.96800	9.97006	9.97205	9.97397	9.97581	9.97759	9.97930
24	.96590	.96803	.97009	.97208	.97400	.97584	.97762	.97933
28	.96594	.96807	.97012	.97211	.97403	.97587	.97765	.97936
32	.96597	.96810	.97016	.97214	.97406	.97591	.97768	.97939
36	.96601	.96814	.97019	.97218	.97409	.97594	.97771	.97941
40	9.96604	9.96817	9.97022	9.97221	9.97412	9.97597	9.97774	9.97944
44	.96608	.96821	.97026	.97224	.97415	.97600	.97777	.97947
48	.96612	.96824	.97029	.97227	.97418	.97603	.97780	.97950
52	.96615	.96827	.97033	.97231	.97422	.97606	.97783	.97953
56	.96619	.96831	.97036	.97234	.97425	.97609	.97785	.97955
s	$9^h 53^m$	$9^h 57^m$	$10^h 1^m$	$10^h 5^m$	$10^h 9^m$	$10^h 13^m$	$10^h 17^m$	$10^h 21^m$
0	9.96622	9.96834	9.97039	9.97237	9.97428	9.97612	9.97788	9.97958
4	.96626	.96837	.97043	.97240	.97431	.97615	.97791	.97961
8	.96630	.96841	.97046	.97244	.97434	.97618	.97794	.97964
12	.96633	.96845	.97049	.97247	.97437	.97621	.97797	.97966
16	.96637	.96848	.97052	.97250	.97440	.97624	.97800	.97969
20	9.96640	9.96852	9.97056	9.97253	9.97443	9.97627	9.97803	9.97972
24	.96644	.96855	.97059	.97257	.97447	.97630	.97806	.97975
28	.96648	.96859	.97063	.97260	.97450	.97633	.97808	.97977
32	.96651	.96862	.97066	.97263	.97453	.97636	.97811	.97980
36	.96655	.96866	.97069	.97266	.97456	.97639	.97814	.97983
40	9.96658	9.96869	9.97073	9.97269	9.97459	9.97642	9.97817	9.97986
44	.96662	.96873	.97076	.97273	.97462	.97645	.97820	.97988
48	.96665	.96876	.97079	.97276	.97465	.97647	.97823	.97991
52	.96669	.96879	.97083	.97279	.97468	.97650	.97826	.97994
56	.96673	.96883	.97086	.97282	.97471	.97653	.97829	.97997
s	$9^h 54^m$	$9^h 58^m$	$10^h 2^m$	$10^h 6^m$	$10^h 10^m$	$10^h 14^m$	$10^h 18^m$	$10^h 22^m$
0	9.96676	9.96886	9.97089	9.97285	9.97474	9.97656	9.97831	9.97999
4	.96680	.96890	.97093	.97289	.94478	.97659	.97834	.98002
8	.96683	.96894	.97096	.96292	.97481	.97662	.97837	.98005
12	.96687	.96897	.97099	.97295	.97484	.97665	.97840	.98008
16	.96690	.96900	.97103	.97298	.97487	.97668	.97843	.98010
20	9.96694	9.96904	9.97106	9.97301	9.97490	9.97671	9.97846	9.98013
24	.96697	.96907	.97109	.97305	.97493	.97674	.97849	.98016
28	.96701	.96910	.97113	.97308	.97496	.97677	.97851	.98019
32	.96705	.96914	.97116	.97311	.97499	.97680	.97854	.98021
36	.96708	.96917	.97119	.97314	.97502	.97683	.97857	.98024
40	9.96712	9.96921	9.97123	9.97317	9.97505	9.97686	9.97860	9.98027
44	.96715	.96924	.97126	.97321	.97508	.97689	.97863	.98030
48	.96719	.96928	.97129	.97324	.97511	.97692	.97866	.98032
52	.96722	.96931	.97132	.97327	.97514	.97695	.97868	.98035
56	.96726	.96934	.97136	.97330	.97518	.97698	.97871	.98038
s	$9^h 55^m$	$9^h 59^m$	$10^h 3^m$	$10^h 7^m$	$10^h 11^m$	$10^h 15^m$	$10^h 19^m$	$10^h 23^m$
0	9.96729	9.96938	9.97139	9.97333	9.97521	9.97701	9.97874	9.98040
4	.96733	.96941	.97142	.97337	.97524	.97704	.97877	.98043
8	.96736	.96945	.97146	.97340	.97527	.97707	.97880	.98046
12	.96740	.96948	.97149	.97343	.97530	.97710	.97883	.98049
16	.96743	.96951	.97152	.97346	.97533	.97713	.97885	.98051
20	9.96747	9.96955	9.97156	9.97349	9.97536	9.97716	9.97888	9.98054
24	.96750	.96958	.97159	.97352	.97539	.97718	.97891	.98057
28	.96754	.96962	.97162	.97356	.97542	.97721	.97894	.98059
32	.96758	.96965	.97165	.97359	.97545	.97724	.97897	.98062
36	.98761	.96968	.97169	.97362	.97548	.97727	.97899	.98065
40	9.96765	9.96972	9.97172	9.97365	9.97551	9.97730	9.97902	9.98067
44	.96768	.96975	.97175	.97368	.97554	.97733	.97905	.98070
48	.96772	.96979	.97179	.97371	.97557	.97736	.97908	.98073
52	.96775	.96982	.97182	.97375	.97560	.97739	.97911	.98076
56	.96779	.96985	.97185	.97378	.97563	.97742	.97914	.98078
60	9.96782	9.96989	9.97188	9.97381	9.97566	9.97745	9.97916	9.98081

s	$10^h 24^m$	$10^h 28^m$	$10^h 32^m$	$10^h 36^m$	$10^h 40^m$	$10^h 44^m$	$10^h 48^m$	$10^h 52^m$
	Hav.	Hav.	Hav.	Hav.	Hav.	Hav.	Hav.	Hav.
0	9.98081	9.98239	9.98389	9.98533	9.98670	9.98801	9.98924	9.99041
4	.98084	.98241	.98392	.98536	.98673	.98803	.98926	.99043
8	.98086	.98244	.98394	.98538	.98675	.98805	.98928	.99044
12	.98089	.98246	.98397	.98540	.98677	.98807	.98930	.99046
16	.98092	.98249	.98399	.98543	.98679	.98809	.98932	.99048
20	9.98094	9.98251	9.98402	9.98545	9.98681	9.98811	9.98934	9.99050
24	.98097	.98254	.98404	.98547	.98684	.98813	.98936	.99052
28	.98100	.98256	.98406	.98550	.98686	.98815	.98938	.99054
32	.98102	.98259	.98409	.98552	.98688	.98817	.98940	.99056
36	.98105	.98262	.98411	.98554	.98690	.98819	.98942	.99058
40	9.98108	9.98264	9.98414	9.98557	9.98692	9.98822	9.98944	9.99059
44	.98110	.98267	.98416	.98559	.98695	.98824	.98946	.99061
48	.98113	.98269	.98419	.98561	.98697	.98826	.98948	.99063
52	.98116	.98272	.98421	.98564	.98699	.98828	.98950	.99065
56	.98118	.98274	.98424	.98566	.98701	.98830	.98952	.99067

s	$10^h 25^m$	$10^h 29^m$	$10^h 33^m$	$10^h 37^m$	$10^h 41^m$	$10^h 45^m$	$10^h 49^m$	$10^h 53^m$
0	9.98121	9.98277	9.98426	9.98568	9.98703	9.98832	9.98954	9.99069
4	.98124	.98279	.98428	.98570	.98706	.98834	.98956	.99071
8	.98126	.98282	.98431	.98573	.98708	.98836	.98958	.99072
12	.98129	.98285	.98433	.98575	.98710	.98838	.98960	.99074
16	.98132	.98287	.98436	.98577	.98712	.98840	.98962	.99076
20	9.98134	9.98290	9.98438	9.98580	9.98714	9.98842	9.98964	9.99078
24	.98137	.98292	.98440	.98582	.98717	.98845	.98966	.99080
28	.98139	.98295	.98443	.98584	.98719	.98847	.98968	.99082
32	.98142	.98297	.98445	.98587	.98721	.98849	.98970	.99084
36	.98145	.98300	.98448	.98589	.98723	.98851	.98971	.99085
40	9.98147	9.98302	9.98450	9.98591	9.98725	9.98853	9.98973	9.99087
44	.98150	.98305	.98453	.98593	.98728	.98855	.98975	.99089
48	.98153	.98307	.98455	.98596	.98730	.98857	.98977	.99091
52	.98155	.98310	.98457	.98598	.98732	.98859	.98979	.99093
56	.98158	.98312	.98460	.98600	.98734	.98861	.98981	.99095

s	$10^h 26^m$	$10^h 30^m$	$10^h 34^m$	$10^h 38^m$	$10^h 42^m$	$10^h 46^m$	$10^h 50^m$	$10^h 54^m$
0	9.98161	9.98315	9.98462	9.98603	9.98736	9.98863	9.98983	9.99096
4	.98163	.98317	.98465	.98605	.98738	.98865	.98985	.99098
8	.98166	.98320	.98467	.98607	.98741	.98867	.98987	.99100
12	.98168	.98322	.98469	.98609	.98743	.98869	.98989	.99102
16	.98171	.98325	.98472	.98612	.98745	.98871	.98991	.99104
20	9.98174	9.98327	9.98474	9.98614	9.98747	9.98873	9.98993	9.99106
24	.98176	.98330	.98476	.98616	.98749	.98875	.98995	.99107
28	.98179	.98332	.98479	.98619	.98751	.98877	.98997	.99109
32	.98182	.98335	.98481	.98621	.98754	.98880	.98999	.99111
36	.98184	.98337	.98484	.98623	.98756	.98882	.99001	.99113
40	9.98187	9.98340	9.98486	9.98625	9.98758	9.98884	9.99003	9.99115
44	.98189	.98342	.98488	.98628	.98760	.98886	.99004	.99116
48	.98192	.98345	.98491	.98630	.98762	.98888	.99006	.99118
52	.98195	.98347	.98493	.98632	.98764	.98890	.99008	.99120
56	.98197	.98350	.98496	.98634	.98766	.98892	.99010	.99122

s	$10^h 27^m$	$10^h 31^m$	$10^h 35^m$	$10^h 39^m$	$10^h 43^m$	$10^h 47^m$	$10^h 51^m$	$10^h 55^m$
0	9.98200	9.98352	9.98498	9.98637	9.98769	9.98894	9.99012	9.99124
4	.98202	.98355	.98500	.98639	.98771	.98896	.99014	.99126
8	.98205	.98357	.98503	.98641	.98773	.98898	.99016	.99127
12	.98208	.98360	.98505	.98643	.98775	.98900	.99018	.99129
16	.98210	.98362	.98507	.98646	.98777	.98902	.99020	.99131
20	9.98213	9.98365	9.98510	9.98648	9.98779	9.98904	9.99022	9.99133
24	.98215	.98367	.98512	.98650	.98781	.98906	.99024	.99135
28	.98218	.98370	.98514	.98652	.98784	.98908	.99026	.99136
32	.98221	.98372	.98517	.98655	.98786	.98910	.99027	.99138
36	.98223	.98375	.98519	.98657	.98788	.98912	.99029	.99140
40	9.98226	9.98377	9.98521	9.98659	9.98790	9.98914	9.99031	9.99142
44	.98228	.98379	.98524	.98661	.98792	.98916	.99033	.99143
48	.98231	.98382	.98526	.98664	.98794	.98918	.99035	.99145
52	.98233	.98384	.98529	.98666	.98796	.98920	.99037	.99147
56	.98236	.98387	.98531	.98668	.98798	.98922	.99039	.99149
60	9.98239	9.98389	9.98533	9.98670	9.98801	9.98924	9.99041	9.99151

s	$10^h 56^m$	$11^h 0^m$	$11^h 4^m$	$11^h 8^m$	$11^h 12^m$	$11^h 16^m$	$11^h 20^m$	$11^h 24^m$
	Hav.	**Hav.**	**Hav.**	**Hav.**	**Hav.**	**Hav.**	**Hav.**	**Hav.**
0	9.99151	9.99254	9.99350	9.99440	9.99523	9.99599	9.99669	9.99732
4	.99152	.99255	.99352	.99441	.99524	.99600	.99670	.99733
8	.99154	.99257	.99353	.99443	.99526	.99602	.99671	.99734
12	.99156	.99259	.99355	.99444	.99527	.99603	.99672	.99735
16	.99158	.99260	.99356	.99446	.99528	.99604	.99673	.99736
20	9.99159	9.99262	9.99358	9.99447	9.99529	9.99605	9.99674	9.99737
24	.99161	.99264	.99359	.99448	.99531	.99606	.99675	.99738
28	.99163	.99265	.99361	.99450	.99532	.99608	.99677	.99739
32	.99165	.99267	.99362	.99451	.99533	.99609	.99678	.99740
36	.99166	.99269	.99364	.99453	.99535	.99610	.99679	.99741
40	9.99168	9.99270	9.99366	9.99454	9.99536	9.99611	9.99680	9.99742
44	.99170	.99272	.99367	.99456	.99537	.99612	.99681	.99743
48	.99172	.99274	.99369	.99457	.99539	.99614	.99682	.99744
52	.99173	.99275	.99370	.99458	.99540	.99615	.99683	.99745
56	.99175	.99277	.99372	.99460	.99541	.99616	.99684	.99746
s	$10^h 57^m$	$11^h 1^m$	$11^h 5^m$	$11^h 9^m$	$11^h 13^m$	$11^h 17^m$	$11^h 21^m$	$11^h 25^m$
0	9.99177	9.99278	9.99373	9.99461	9.99543	9.99617	9.99685	9.99747
4	.99179	.99280	.99375	.99463	.99544	.99618	.99686	.99748
8	.99180	.99282	.99376	.99464	.99545	.99620	.99687	.99748
12	.99182	.99283	.99378	.99465	.99546	.99621	.99688	.99749
16	.99184	.99285	.99379	.99467	.99548	.99622	.99690	.99750
20	9.99186	9.99287	9.99381	9.99468	9.99549	9.99623	9.99691	9.99751
24	.99187	.99288	.99382	.99470	.99550	.99624	.99692	.99752
28	.99189	.99290	.99384	.99471	.99552	.99626	.99693	.99753
32	.99191	.99291	.99385	.99472	.99553	.99627	.99694	.99754
36	.99193	.99293	.99387	.99474	.99554	.99628	.99695	.99755
40	9.99194	9.99295	9.99388	9.99475	9.99555	9.99629	9.99696	9.99756
44	.99196	.99296	.99390	.99477	.99557	.99630	.99697	.99757
48	.99198	.99298	.99391	.99478	.99558	.99631	.99698	.99758
52	.99200	.99300	.99393	.99479	.99559	.99633	.99699	.99759
56	.99201	.99301	.99394	.99481	.99561	.99634	.99700	.99760
s	$10^h 58^m$	$11^h 2^m$	$11^h 6^m$	$11^h 10^m$	$11^h 14^m$	$11^h 18^m$	$11^h 22^m$	$11^h 26^m$
0	9.99203	9.99303	9.99396	9.99482	9.99562	9.99635	9.99701	9.99761
4	.99205	.99304	.99397	.99484	.99563	.99636	.99702	.99762
8	.99206	.99306	.99399	.99485	.99564	.99637	.99703	.99763
12	.99208	.99308	.99400	.99486	.99566	.99638	.99704	.99764
16	.99210	.99309	.99402	.99488	.99567	.99639	.99705	.99765
20	9.99212	9.99311	9.99403	9.99489	9.99568	9.99641	9.99706	9.99766
24	.99213	.99312	.99405	.99490	.99569	.99642	.99707	.99766
28	.99215	.99314	.99406	.99492	.99571	.99643	.99708	.99767
32	.99217	.99316	.99408	.99493	.99572	.99644	.99710	.99768
36	.99218	.99317	.99409	.99495	.99573	.99645	.99711	.99769
40	9.99220	9.99319	9.99411	9.99496	9.99575	9.99646	9.99712	9.99770
44	.99222	.99320	.99412	.99497	.99576	.99648	.99713	.99771
48	.99223	.99322	.99414	.99499	.99577	.99649	.99714	.99772
52	.99225	.99324	.99415	.99500	.99578	.99650	.99715	.99773
56	.99227	.99325	.99417	.99501	.99580	.99651	.99716	.99774
s	$10^h 59^m$	$11^h 3^m$	$11^h 7^m$	$11^h 11^m$	$11^h 15^m$	$11^h 19^m$	$11^h 23^m$	$11^h 27^m$
0	9.99229	9.99327	9.99418	9.99503	9.99581	9.99652	9.99717	9.99774
4	.99230	.99328	.99420	.99504	.99582	.99653	.99718	.99775
8	.99232	.99330	.99421	.99505	.99583	.99654	.99719	.99776
12	.99234	.99331	.99422	.99507	.99584	.99655	.99720	.99777
16	.99235	.99333	.99424	.99508	.99586	.99657	.99721	.99778
20	9.99237	9.99335	9.99425	9.99510	9.99587	9.99658	9.99722	9.99779
24	.99239	.99336	.99427	.99511	.99588	.99659	.99723	.99780
28	.99240	.99338	.99429	.99512	.99589	.99660	.99724	.99781
32	.99242	.99339	.99430	.99514	.99591	.99661	.99725	.99782
36	.99244	.99341	.99431	.99515	.99592	.99662	.99726	.99783
40	9.99245	9.99342	9.99433	9.99516	9.99593	9.99663	9.99727	9.99784
44	.99247	.99344	.99434	.99518	.99594	.99664	.99728	.99785
48	.99249	.99345	.99436	.99519	.99596	.99666	.99729	.99786
52	.99250	.99347	.99437	.99520	.99597	.99667	.99730	.99786
56	.99252	.99349	.99438	.99522	.99598	.99668	.99731	.99787
60	9.99254	9.99350	9.99440	9.99523	9.99599	9.99669	9.99732	9.99788

s	$11^h 28^m$	$11^h 32^m$	$11^h 36^m$	$11^h 40^m$	$11^h 44^m$	$11^h 48^m$	$11^h 52^m$	$11^h 56^m$
	Hav.	**Hav.**	**Hav.**	**Hav.**	**Hav.**	**Hav.**	**Hav.**	**Hav.**
0	9.99788	9.99838	9.99881	9.99917	9.99947	9.99970	9.99987	9.99997
4	.99789	.99839	.99882	.99918	.99948	.99971	.99987	.99997
8	.99790	.99839	.99882	.99918	.99948	.99971	.99987	.99997
12	.99791	.99840	.99883	.99919	.99948	.99971	.99987	.99997
16	.99792	.99841	.99884	.99919	.99949	.99972	.99988	.99997
20	9.99793	9.99842	9.99884	9.99920	9.99949	9.99972	9.99988	9.99997
24	.99793	.99842	.99885	.99921	.99950	.99972	.99988	.99997
28	.99794	.99843	.99885	.99921	.99950	.99973	.99988	.99997
32	.99795	.99844	.99886	.99922	.99951	.99973	.99988	.99998
36	.99796	.99845	.99887	.99922	.99951	.99973	.99989	.99998
40	9.99797	9.99845	9.99887	9.99923	9.99951	9.99973	9.99989	9.99998
44	.99798	.99846	.99888	.99923	.99952	.99974	.99989	.99998
48	.99799	.99847	.99889	.99924	.99952	.99974	.99989	.99998
52	.99800	.99848	.99889	.99924	.99953	.99974	.99989	.99998
56	.99800	.99848	.99890	.99925	.99953	.99975	.99990	.99998

s	$11^h 29^m$	$11^h 33^m$	$11^h 37^m$	$11^h 41^m$	$11^h 45^m$	$11^h 49^m$	$11^h 53^m$	$11^h 57^m$
0	9.99801	9.99849	9.99891	9.99925	9.99953	9.99975	9.99990	9.99998
4	.99802	.99850	.99891	.99926	.99954	.99975	.99990	.99998
8	.99803	.99851	.99892	.99926	.99954	.99976	.99990	.99998
12	.99804	.99851	.99893	.99927	.99954	.99976	.99990	.99998
16	.99805	.99852	.99893	.99927	.99955	.99976	.99991	.99998
20	9.99805	9.99853	9.99894	9.99928	9.99955	9.99976	9.99991	9.99999
24	.99806	.99854	.99894	.99928	.99956	.99977	.99991	.99999
28	.99807	.99854	.99895	.99929	.99956	.99977	.99991	.99999
32	.99808	.99855	.99896	.99929	.99957	.99977	.99991	.99999
36	.99809	.99856	.99896	.99930	.99957	.99978	.99992	.99999
40	9.99810	9.99857	9.99897	9.99931	9.99958	9.99978	9.99992	9.99999
44	.99811	.99857	.99897	.99931	.99958	.99978	.99992	.99999
48	.99811	.99858	.99898	.99932	.99958	.99978	.99992	.99999
52	.99812	.99859	.99899	.99932	.99959	.99979	.99992	.99999
56	.99813	.99859	.99899	.99933	.99959	.99979	.99992	.99999

s	$11^h 30^m$	$11^h 34^m$	$11^h 38^m$	$11^h 42^m$	$11^h 46^m$	$11^h 50^m$	$11^h 54^m$	$11^h 58^m$
0	9.99814	9.99860	9.99900	9.99933	9.99959	9.99979	9.99993	9.99999
4	.99815	.99861	.99901	.99934	.99960	.99980	.99993	.99999
8	.99815	.99862	.99901	.99934	.99960	.99980	.99993	.99999
12	.99816	.99862	.99902	.99935	.99961	.99980	.99993	.99999
16	.99817	.99863	.99902	.99935	.99961	.99980	.99993	.99999
20	9.99818	9.99864	9.99903	9.99935	9.99961	9.99981	9.99993	9.99999
24	.99819	.99864	.99904	.99936	.99962	.99981	.99994	.99999
28	.99820	.99865	.99904	.99936	.99962	.99981	.99994	.00000
32	.99820	.99866	.99905	.99937	.99963	.99981	.99994	.00000
36	.99821	.99867	.99905	.99937	.99963	.99982	.99994	.00000
40	9.99822	9.99867	9.99906	9.99938	9.99963	9.99982	9.99994	0.00000
44	.99823	.99868	.99906	.99938	.99964	.99982	.99994	.00000
48	.99824	.99869	.99907	.99939	.99964	.99983	.99994	.00000
52	.99824	.99869	.99908	.99939	.99964	.99983	.99995	.00000
56	.99825	.99870	.99908	.99940	.99965	.99983	.99995	.00000

s	$11^h 31^m$	$11^h 35^m$	$11^h 39^m$	$11^h 43^m$	$11^h 47^m$	$11^h 51^m$	$11^h 55^m$	$11^h 59^m$
0	9.99826	9.99871	9.99909	9.99940	9.99965	9.99983	9.99995	0.00000
4	.99827	.99871	.99909	.99941	.99965	.99983	.99995	.00000
8	.99828	.99872	.99910	.99941	.99966	.99984	.99995	.00000
12	.99828	.99873	.99911	.99942	.99966	.99984	.99995	.00000
16	.99829	.99874	.99911	.99942	.99966	.99984	.99995	.00000
20	9.99830	9.99874	9.99912	9.99943	9.99967	9.99984	9.99996	0.00000
24	.99831	.99875	.99912	.99943	.99967	.99985	.99996	.00000
28	.99832	.99876	.99913	.99943	.99968	.99985	.99996	.00000
32	.99832	.99876	.99913	.99944	.99968	.99985	.99996	.00000
36	.99833	.99877	.99914	.99944	.99968	.99985	.99996	.00000
40	9.99834	9.99878	9.99915	9.99945	9.99969	9.99986	9.99996	0.00000
44	.99835	.99878	.99915	.99945	.99969	.99986	.99996	.00000
48	.99836	.99879	.99916	.99946	.99969	.99986	.99996	.00000
52	.99836	.99880	.99916	.99946	.99970	.99986	.99996	.00000
56	.99837	.99880	.99917	.99947	.99970	.99987	.99997	.00000
60	9.99838	9.99881	9.99917	9.99947	9.99970	9.99987	9.99997	0.00000

Table 11. Azimuth

	T, The Ship's Apparent Time for a Sun Observation, or the Hour-angle for a Star Observation								
Use these in Forenoon →	*12h 0m* *24 0*	*12h 8m* *23 52*	*12h 16m* *23 44*	*12h 24m* *23 36*	*12h 32m* *23 28*	*12h 40m* *23 20*	*12h 48m* *23 12*	*12h 56m* *23 4*	← Use these in Forenoon
Use these in Afternoon →	*0h 0m* *12 0*	*0h 8m* *11 52*	*0h 16m* *11 44*	*0h 24m* *11 36*	*0h 32m* *11 28*	*0h 40m* *11 20*	*0h 48m* *11 12*	*0h 56m* *11 4*	← Use these in Afternoon
Declinations									**Altitudes**
0°	0	349	698	1045	1392	1737	2079	2419	**0°**
2	0	349	697	1045	1391	1736	2078	2417	2
4	0	348	696	1042	1389	1732	2074	2413	4
6	0	347	694	1040	1384	1726	2067	2406	6
8	0	346	691	1035	1378	1720	2059	2395	8
10	0	344	687	1029	1371	1710	2047	2382	**10**
12	0	341	682	1022	1361	1698	2033	2367	12
14	0	339	677	1015	1351	1685	2018	2347	14
16	0	336	671	1005	1338	1669	1998	2326	16
18	0	332	663	994	1323	1651	1977	2301	18
20	0	328	656	982	1308	1632	1954	2274	**20**
22	0	324	647	969	1290	1610	1928	2244	22
24	0	319	637	955	1272	1586	1900	2210	24
26	0	314	627	940	1251	1561	1868	2174	26
28	0	308	616	923	1228	1533	1835	2136	28
30	0	302	604	905	1205	1504	1801	2095	**30**
32	0	296	592	886	1180	1472	1763	2051	32
34	0	289	578	867	1153	1440	1724	2005	34
36	0	282	564	846	1126	1405	1682	1957	36
38	0	275	550	824	1096	1369	1639	1906	38
40	0	267	534	801	1066	1330	1592	1853	**40**
42	0	259	518	777	1034	1290	1545	1798	42
44	0	251	502	752	1001	1249	1496	1740	44
46	0	242	485	726	967	1206	1444	1681	46
48	0	234	467	699	931	1162	1391	1619	48
50	0	224	448	672	895	1116	1337	1555	**50**
52	0	215	429	644	857	1069	1280	1489	52
54	0	205	411	615	818	1021	1222	1422	54
56	0	195	390	585	778	971	1162	1353	56
58	0	185	370	554	738	920	1102	1282	58
60	0	175	349	523	696	868	1040	1210	**60**
62	0	164	328	490	653	815	976	1136	62
64	0	153	306	458	610	761	911	1060	64
66	0	142	284	425	566	706	846	984	66
68	0	131	261	392	521	651	779	906	68
70	0	119	239	358	476	594	711	827	**70**
72	0	108	216	323	430	537	643	748	72
74	0	96	192	288	384	479	573	667	74
76	0	84	169	253	337	420	503	585	76
78	0	73	145	217	289	361	432	503	78
80	0	61	121	182	242	302	361	420	**80**
82	0	49	97	146	194	242	289	337	82
84	0	36	73	109	146	182	217	253	84
86	0	24	49	73	97	121	145	169	86
88	0	12	24	36	49	61	73	84	88
Use these in Forenoon →	0° 180	2° 178	4° 176	6° 174	8° 172	10° 170	12° 168	14° 166	← Use these in Forenoon
Use these in Afternoon →	180° 360	182° 358	184° 356	186° 354	188° 352	190° 350	192° 348	194° 346	← Use these in Afternoon
	True Bearing or Azimuth								

	T, The Ship's Apparent Time for a Sun Observation, or the Hour-angle for a Star Observation							
Use these in Forenoon →	13h 4m 22 56	13h 12m 22 48	13h 20m 22 40	13h 28m 22 32	13h 36m 22 24	13h 44m 22 16	13h 52m 22 8	← Use these in Forenoon
Use these in Afternoon →	1h 4m 10 56	1h 12m 10 48	1h 20m 10 40	1h 28m 10 32	1h 36m 10 24	1h 44m 10 16	1h 52m 10 8	← Use these in Afternoon
Declinations								**Altitudes**
0°	2756	3090	3421	3746	4067	4383	4695	**0°**
2	2755	3088	3418	3744	4065	4381	4692	2
4	2750	3082	3412	3737	4058	4373	4684	4
6	2742	3073	3402	3726	4044	4360	4669	6
8	2730	3060	3387	3710	4028	4341	4649	8
10	2714	3043	3368	3689	4005	4317	4624	**10**
12	2696	3023	3346	3664	3978	4287	4592	12
14	2674	2998	3319	3635	3947	4253	4555	14
16	2650	2970	3288	3600	3910	4214	4513	16
18	2622	2939	3253	3563	3868	4170	4465	18
20	2590	2903	3214	3521	3821	4119	4412	**20**
22	2556	2865	3171	3473	3771	4064	4353	22
24	2519	2823	3125	3422	3715	4005	4288	24
26	2477	2777	3074	3367	3656	3941	4220	26
28	2434	2729	3020	3308	3591	3871	4145	28
30	2387	2676	2962	3244	3522	3796	4065	**30**
32	2337	2620	2900	3177	3449	3718	3981	32
34	2285	2563	2835	3106	3372	3634	3892	34
36	2230	2500	2767	3031	3291	3546	3798	36
38	2172	2435	2696	2952	3205	3454	3699	38
40	2112	2367	2620	2869	3116	3358	3596	**40**
42	2048	2297	2542	2784	3023	3258	3489	42
44	1983	2223	2460	2695	2925	3154	3377	44
46	1914	2147	2375	2602	2826	3045	3261	46
48	1845	2067	2289	2507	2721	2934	3142	48
50	1772	1986	2199	2408	2614	2818	3018	**50**
52	1697	1902	2106	2306	2504	2699	2891	52
54	1620	1818	2010	2202	2391	2577	2759	54
56	1541	1728	1913	2094	2275	2451	2625	56
58	1461	1638	1812	1986	2155	2324	2488	58
60	1378	1545	1710	1874	2033	2192	2347	**60**
62	1294	1451	1606	1759	1909	2058	2204	62
64	1209	1355	1499	1643	1783	1922	2058	64
66	1121	1257	1391	1524	1654	1783	1909	66
68	1032	1158	1281	1404	1524	1643	1759	68
70	943	1057	1169	1281	1391	1499	1606	**70**
72	852	955	1057	1158	1257	1355	1451	72
74	760	852	943	1032	1121	1209	1294	74
76	667	748	827	906	984	1060	1136	76
78	573	643	711	779	846	911	976	78
80	479	537	594	651	706	761	815	**80**
82	384	430	476	521	566	610	653	82
84	288	323	358	392	425	458	491	84
86	192	216	239	261	290	306	328	86
88	96	108	119	131	142	153	164	88
Use these in Forenoon →	16° 164	18° 162	20° 160	22° 158	24° 156	26° 154	28° 152	← Use these in Forenoon
Use these in Afternoon →	196° 344	198° 342	200° 340	202° 338	204° 336	206° 334	208° 332	← Use these in Afternoon
	True Bearing or Azimuth							

	T, The Ship's Apparent Time for a Sun Observation, or the Hour-Angle for a Star Observation								
Use these in Forenoon →	$14^h\ 0^m$ / $22\ \ 0$	$14^h\ 8^m$ / $21\ 52$	$14^h\ 16^m$ / $21\ 44$	$14^h\ 24^m$ / $21\ 36$	$14^h\ 32^m$ / $21\ 28$	$14^h\ 40^m$ / $21\ 20$	$14^h\ 48^m$ / $21\ 12$	$14^h\ 56^m$ / $21\ \ 4$	← Use these in Forenoon
Use these in Afternoon →	$2^h\ 0^m$ / $10\ \ 0$	$2^h\ 8^m$ / $9\ 52$	$2^h\ 16^m$ / $9\ 44$	$2^h\ 24^m$ / $9\ 36$	$2^h\ 32^m$ / $9\ 28$	$2^h\ 40^m$ / $9\ 20$	$2^h\ 48^m$ / $9\ 12$	$2^h\ 56^m$ / $9\ \ 4$	← Use these in Afternoon
Declinations									Altitudes
0°	5000	5299	5593	5878	6156	6428	6691	6947	0°
2	4997	5297	5589	5875	6153	6424	6688	6942	2
4	4987	5286	5578	5864	6142	6412	6676	6929	4
6	4973	5270	5562	5845	6124	6393	6655	6908	6
8	4951	5248	5538	5821	6096	6365	6627	6879	8
10	4923	5219	5507	5789	6063	6330	6591	6841	**10**
12	4891	5183	5470	5749	6022	6288	6545	6795	12
14	4852	5141	5426	5703	5973	6237	6492	6741	14
16	4806	5094	5375	5650	5919	6179	6433	6677	16
18	4755	5040	5319	5590	5856	6113	6363	6607	18
20	4699	4979	5255	5524	5785	6040	6288	6528	**20**
22	4635	4914	5184	5450	5709	5960	6204	6440	22
24	4567	4841	5109	5370	5624	5872	6112	6346	24
26	4493	4763	5025	5283	5534	5777	6015	6243	26
28	4415	4678	4938	5190	5437	5675	5907	6134	28
30	4330	4588	4843	5091	5332	5567	5794	6016	**30**
32	4240	4493	4742	4984	5222	5451	5674	5891	32
34	4145	4393	4635	4873	5104	5328	5547	5758	34
36	4044	4287	4524	4755	4980	5200	5414	5619	36
38	3941	4176	4407	4633	4852	5065	5272	5474	38
40	3830	4060	4284	4503	4717	4923	5126	5321	**40**
42	3715	3939	4156	4368	4575	4776	4973	5162	42
44	3596	3812	4023	4229	4429	4624	4812	4997	44
46	3473	3681	3885	4083	4277	4465	4648	4825	46
48	3346	3546	3742	3932	4120	4301	4477	4648	48
50	3214	3406	3594	3779	3958	4131	4301	4465	**50**
52	3078	3263	3443	3619	3790	3958	4120	4277	52
54	2939	3115	3287	3454	3619	3779	3932	4083	54
56	2796	2963	3127	3287	3443	3594	3742	3885	56
58	2650	2808	2963	3115	3263	3406	3546	3681	58
60	2500	2650	2796	2939	3078	3214	3346	3473	**60**
62	2347	2488	2625	2760	2891	3018	3142	3261	62
64	2192	2324	2451	2577	2699	2818	2934	3045	64
66	2033	2155	2275	2391	2504	2614	2721	2826	66
68	1874	1986	2094	2202	2306	2408	2507	2602	68
70	1710	1812	1913	2010	2106	2199	2289	2375	**70**
72	1545	1638	1728	1817	1902	1986	2067	2147	72
74	1378	1461	1541	1620	1697	1720	1845	1914	74
76	1210	1282	1353	1422	1489	1555	1619	1681	76
78	1040	1102	1162	1222	1280	1337	1391	1444	78
80	868	920	971	1021	1069	1116	1162	1206	**80**
82	696	738	778	818	857	895	931	967	82
84	523	554	585	615	644	672	699	726	84
86	349	370	390	411	429	448	467	485	86
88	175	185	195	205	215	224	234	242	88
Use these in Forenoon →	30° / 150	32° / 148	34° / 146	36° / 144	38° / 142	40° / 140	42° / 138	44° / 136	← Use these in Forenoon
Use these in Afternoon →	210° / 330	212° / 328	214° / 326	216° / 324	218° / 322	220° / 320	222° / 318	224° / 316	← Use these in Afternoon
	True Bearing or Azimuth								

	T, The Ship's Apparent Time for a Sun Observation, or the Hour-angle for a Star Observation							
Use these in Forenoon →	$15^h\ 4^m$	$15^h\ 12^m$	$15^h\ 20^m$	$15^h\ 28^m$	$15^h\ 36^m$	$15^h\ 44^m$	$15^h\ 52^m$	← Use these in Forenoon
	20 56	20 48	20 40	20 32	20 24	20 16	20 8	
Use these in Afternoon →	$3^h\ 4^m$	$3^h\ 12^m$	$3^h\ 20^m$	$3^h\ 28^m$	$3^h\ 36^m$	$3^h\ 44^m$	$3^h\ 52^m$	← Use these in Afternoon
	8 56	8 48	8 40	8 32	8 24	8 16	8 8	
Declinations								**Altitudes**
0°	7193	7432	7661	7879	8091	8290	8480	**0°**
2	7190	7427	7656	7875	8085	8285	8476	2
4	7176	7413	7642	7861	8071	8269	8461	4
6	7153	7391	7619	7836	8046	8245	8433	6
8	7124	7358	7586	7803	8011	8210	8399	8
10	7084	7318	7544	7761	7968	8164	8352	**10**
12	7036	7269	7494	7707	7914	8110	8284	12
14	6979	7211	7433	7645	7850	8044	8228	14
16	6915	7144	7364	7575	7776	7969	8153	16
18	6841	7068	7286	7494	7695	7884	8065	18
20	6759	6984	7197	7404	7603	7791	7969	**20**
22	6670	6890	7103	7307	7501	7686	7863	22
24	6572	6789	6998	7199	7391	7573	7749	24
26	6466	6679	6885	7082	7271	7450	7623	26
28	6352	6561	6764	6958	7144	7319	7489	28
30	6230	6436	6634	6825	7006	7180	7345	**30**
32	6101	6302	6497	6683	6861	7031	7191	32
34	5964	6160	6351	6533	6707	6873	7031	34
36	5820	6012	6197	6375	6545	6707	6861	36
38	5669	5856	6037	6210	6375	6533	6683	38
40	5511	5693	5868	6037	6197	6351	6497	**40**
42	5346	5522	5693	5856	6012	6160	6302	42
44	5175	5346	5511	5669	5820	5964	6101	44
46	4997	5162	5321	5474	5619	5758	5891	46
48	4812	4973	5126	5272	5414	5547	5674	48
50	4624	4776	4923	5065	5200	5328	5451	**50**
52	4429	4575	4717	4852	4980	5104	5222	52
54	4229	4368	4503	4633	4755	4873	4984	54
56	4023	4156	4284	4407	4524	4635	4742	56
58	3812	3939	4060	4176	4287	4393	4493	58
60	3596	3715	3830	3941	4044	4145	4240	**60**
62	3378	3489	3596	3700	3798	3892	3981	62
64	3154	3258	3358	3454	3546	3634	3718	64
66	2925	3023	3116	3205	3291	3372	3449	66
68	2695	2784	2869	2952	3031	3106	3177	68
70	2460	2542	2620	2696	2767	2835	2900	**70**
72	2223	2297	2367	2435	2500	2563	2620	72
74	1983	2048	2112	2172	2230	2285	2337	74
76	1740	1798	1853	1906	1957	2005	2051	76
78	1496	1545	1592	1639	1682	1724	1763	78
80	1249	1290	1330	1369	1405	1440	1472	**80**
82	1001	1034	1066	1096	1126	1153	1180	82
84	752	777	801	824	846	867	886	84
86	502	518	534	550	564	578	592	86
88	251	259	267	275	282	289	296	88
Use these in Forenoon →	46°	48°	50°	52°	54°	56°	58°	← Use these in Forenoon
	134	132	130	128	126	124	122	
Use these in Afternoon →	226°	228°	230°	232°	234°	236°	238°	← Use these in Afternoon
	314	312	310	308	306	304	302	
	True Bearing or Azimuth							

	T, The Ship's Apparent Time for a Sun Observation, or the Hour-angle for a Star Observation								
Use these in Forenoon →	16h 0m 20 0	16h 8m 19 52	16h 16m 19 44	16h 24m 19 36	16h 32m 19 28	16h 40m 19 20	16h 48m 19 12	16h 56m 19 4	← Use these in Forenoon
Use these in Afternoon →	4h 0m 8 0	4h 8m 7 52	4h 16m 7 44	4h 24m 7 36	4h 32m 7 28	4h 40m 7 20	4h 48m 7 12	4h 56m 7 4	→ Use these in Afternoon
Declinations 0°	8660	8828	8989	9135	9272	9397	9510	9612	0° Altitudes
2	8656	8824	8982	9131	9266	9391	9506	9607	2
4	8640	8808	8966	9114	9249	9374	9486	9590	4
6	8612	8780	8939	9084	9221	9346	9458	9561	6
8	8576	8744	8900	9046	9181	9305	9419	9519	8
10	8529	8696	8851	8997	9131	9253	9367	9466	**10**
12	8470	8636	8792	8935	9069	9191	9303	9401	12
14	8403	8567	8722	8863	8997	9118	9228	9326	14
16	8326	8487	8640	8782	8913	9033	9143	9241	16
18	8235	8397	8549	8688	8818	8937	9044	9143	18
20	8137	8296	8447	8584	8714	8831	8937	9033	**20**
22	8030	8187	8333	8470	8596	8714	8818	8913	22
24	7912	8067	8212	8347	8470	8584	8688	8782	24
26	7784	7936	8078	8212	8333	8447	8549	8640	26
28	7647	7796	7936	8067	8187	8296	8397	8487	28
30	7501	7647	7784	7912	8030	8137	8235	8326	**30**
32	7345	7489	7623	7749	7863	7969	8065	8153	32
34	7180	7319	7450	7573	7686	7791	7884	7969	34
36	7006	7144	7271	7391	7501	7603	7695	7776	36
38	6825	6958	7082	7199	7307	7404	7494	7575	38
40	6634	6764	6885	6998	7103	7197	7286	7364	**40**
42	6436	6561	6679	6789	6890	6984	7068	7144	42
44	6230	6352	6466	6572	6670	6759	6841	6915	44
46	6016	6134	6243	6346	6440	6528	6607	6677	46
48	5794	5907	6015	6212	6204	6288	6363	6433	48
50	5567	5675	5777	5872	5960	6040	6113	6179	**50**
52	5332	5437	5534	5624	5709	5785	5856	5919	52
54	5091	5190	5283	5370	5450	5524	5590	5650	54
56	4843	4938	5025	5109	5184	5255	5319	5375	56
58	4588	4678	4763	4841	4914	4979	5040	5094	58
60	4330	4415	4493	4567	4635	4699	4755	4806	**60**
62	4065	4145	4220	4288	4353	4412	4465	4513	62
64	3796	3871	3941	4005	4064	4119	4170	4214	64
66	3522	3591	3656	3715	3771	3821	3868	3910	66
68	3244	3308	3367	3422	3473	3521	3563	3600	68
70	2962	3020	3074	3125	3171	3214	3253	3288	**70**
72	2676	2729	2777	2823	2865	2903	2939	2970	72
74	2387	2434	2477	2519	2556	2590	2622	2650	74
76	2095	2136	2174	2210	2244	2274	2301	2326	76
78	1801	1835	1868	1900	1928	1954	1977	1998	78
80	1504	1533	1561	1586	1610	1632	1651	1669	**80**
82	1205	1228	1251	1272	1290	1308	1323	1338	82
84	905	923	940	955	969	982	994	1005	84
86	604	616	627	637	647	656	663	671	86
88	302	308	314	319	324	328	332	336	88
Use these in Forenoon →	60° 120	62° 118	64° 116	66° 114	68° 112	70° 110	72° 108	74° 106	← Use these in Forenoon
Use these in Afternoon →	240° 300	242° 298	244° 296	246° 294	248° 292	250° 290	252° 288	254° 286	← Use these in Afternoon
	True Bearing or Azimuth								

	T, The Ship's Apparent Time for a Sun Observation, or the Hour-angle for a Star Observation								
Use these in Forenoon →	$17^h\ 4^m$ 18 56	$17^h\ 12^m$ 18 48	$17^h\ 20^m$ 18 40	$17^h\ 28^m$ 18 32	$17^h\ 36^m$ 18 24	$17^h\ 44^m$ 18 16	$17^h\ 52^m$ 18 8	$18^h\ 0^m$ 18 0	← Use these in Forenoon
Use these in Afternoon →	$5^h\ 4^m$ 6 56	$5^h\ 12^m$ 6 48	$5^h\ 20^m$ 6 40	$5^h\ 28^m$ 6 32	$5^h\ 36^m$ 6 24	$5^h\ 44^m$ 6 16	$5^h\ 52^m$ 6 8	$6^h\ 0^m$ 6 0	← Use these in Afternoon
Declinations									Altitudes
0°	9703	9781	9849	9904	9945	9974	9993	10000	**0°**
2	9696	9774	9842	9897	9940	9970	9988	9993	2
4	9679	9757	9824	9879	9922	9951	9970	9974	4
6	9649	9727	9795	9849	9891	9922	9940	9945	6
8	9610	9687	9752	9806	9849	9879	9897	9904	8
10	9557	9634	9699	9752	9795	9824	9842	9849	**10**
12	9491	9568	9634	9687	9727	9757	9774	9781	12
14	9414	9491	9557	9610	9649	9679	9696	9703	14
16	9326	9401	9466	9519	9561	9590	9607	9612	16
18	9228	9303	9367	9419	9458	9486	9506	9510	18
20	9118	9191	9253	9305	9346	9374	9391	9397	**20**
22	8997	9069	9131	9181	9221	9249	9266	9272	22
24	8863	8935	8997	9046	9084	9114	9131	9135	24
26	8722	8792	8851	8900	8939	8966	8982	8989	26
28	8567	8636	8696	8744	8780	8808	8824	8828	28
30	8403	8470	8529	8576	8612	8640	8656	8660	**30**
32	8228	8284	8352	8399	8433	8461	8476	8480	32
34	8044	8110	8164	8210	8245	8269	8285	8290	34
36	7850	7914	7968	8011	8046	8071	8085	8091	36
38	7645	7707	7761	7803	7836	7861	7875	7879	38
40	7433	7494	7544	7586	7619	7642	7656	7661	**40**
42	7211	7269	7318	7358	7391	7413	7427	7432	42
44	6979	7036	7084	7124	7153	7176	7190	7193	44
46	6741	6795	6841	6879	6908	6929	6942	6947	46
48	6492	6545	6591	6627	6655	6676	6688	6691	48
50	6237	6288	6330	6365	6393	6412	6424	6428	**50**
52	5973	6022	6063	6096	6124	6142	6153	6156	52
54	5703	5749	5789	5821	5845	5864	5875	5878	54
56	5426	5470	5507	5538	5562	5578	5589	5593	56
58	5141	5183	5219	5248	5270	5286	5297	5299	58
60	4852	4891	4923	4951	4973	4987	4997	5000	**60**
62	4555	4592	4624	4649	4669	4684	4692	4695	62
64	4253	4287	4317	4341	4360	4373	4381	4383	64
66	3947	3978	4005	4028	4044	4058	4065	4067	66
68	3635	3664	3689	3710	3726	3737	3744	3746	68
70	3319	3346	3368	3387	3402	3412	3418	3421	**70**
72	2998	3023	3043	3060	3073	3082	3088	3090	72
74	2674	2696	2714	2730	2742	2750	2755	2756	74
76	2347	2367	2382	2395	2406	2413	2417	2419	76
78	2018	2033	2047	2059	2067	2074	2078	2079	78
80	1685	1698	1710	1720	1726	1732	1736	1737	**80**
82	1351	1361	1371	1378	1384	1389	1391	1392	82
84	1015	1022	1029	1035	1040	1042	1045	1045	84
86	677	682	687	691	694	696	697	698	86
88	339	341	344	346	347	348	349	349	88
Use these in Forenoon →	76° 104	78° 102	80° 100	82° 98	84° 96	86° 94	88° 92	90° 90	← Use these in Forenoon
Use these in Afternoon →	256° 284	258° 282	260° 280	262° 278	264° 276	266° 274	268° 272	270° 270	← Use these in Afternoon
	True Bearing or Azimuth								

Table 12. Auxiliary Azimuth Table

Latitude	Declinations												
	0°	2°	4°	6°	8°	10°	12°	14°	16°	18°	20°	22°	24°
0°	0°												
2	0	90°											
4	0	30	90°										
6	0	20	42	90°									
8	0	15	30	49	90°								
10	0	12	24	37	53	90°							
12	0	10	20	30	42	57	90°						
14	0	8	17	26	35	46	59	90°					
16	0	7	15	22	30	39	49	61	90°				
18	0	6	13	20	27	34	42	52	63	90°			
20	0	6	12	18	24	31	37	45	54	65	90°		
22	0	5	11	16	22	28	34	40	47	56	66	90°	
24	0	5	10	15	20	25	31	36	43	49	57	67	90°
26	0	5	9	14	19	23	28	34	39	45	51	59	68
28	0	4	9	13	17	22	26	31	36	41	47	53	60
30	0	4	8	12	16	20	25	29	33	38	43	49	54
32	0	4	8	11	15	19	23	27	31	36	40	45	50
34	0	4	7	11	14	18	22	26	30	34	38	42	47
36	0	3	7	10	14	17	21	24	28	32	36	40	44
38	0	3	7	10	13	16	20	23	27	30	34	37	41
40	0	3	6	9	12	16	19	22	25	29	32	36	39
42	0	3	6	9	12	15	18	21	24	28	31	34	37
44	0	3	6	9	12	14	17	20	23	26	30	33	36
46	0	3	6	8	11	14	17	20	23	25	28	31	34
48	0	3	5	8	11	14	16	19	22	25	27	30	33
50	0	3	5	8	10	13	16	18	21	24	27	29	32
52	0	3	5	8	10	13	15	18	20	23	26	28	31
54	0	2	5	7	10	12	15	17	20	22	25	28	30
56	0	2	5	7	10	12	15	17	19	22	24	27	29
58	0	2	5	7	9	12	14	17	19	21	24	26	29
60	0	2	5	7	9	12	14	16	19	21	23	26	28

Table 12. Completed

Latitude	Declinations												
	26°	28°	30°	32°	34°	36°	38°	40°	42°	44°	46°	48°	50°
26°	90°												
28	69	90°											
30	61	70	90°										
32	56	62	71	90°									
34	52	57	63	71	90°								
36	48	53	58	64	72	90°							
38	45	50	54	59	65	73	90°						
40	43	47	51	56	60	66	73	90°					
42	41	45	48	53	57	61	67	74	90°				
44	39	43	46	50	54	58	62	68	74	90°			
46	38	41	44	47	51	55	59	63	68	75	90°		
48	36	39	42	45	49	52	56	60	64	69	75	90°	
50	35	38	41	44	47	50	53	57	61	65	70	76	90°
52	34	37	39	42	45	48	51	55	58	62	66	71	76
54	33	35	38	41	44	47	50	53	56	59	63	67	71
56	32	34	37	40	42	45	48	51	54	57	60	64	68
58	31	33	36	39	41	44	47	49	52	55	58	61	65
60	30	33	35	38	40	43	45	48	51	53	56	59	62

b	a = 0° K	a = 0° Q	a = 1° K	a = 1° Q	a = 2° K	a = 2° Q	a = 3° K	a = 3° Q	a = 4° K	a = 4° Q	a = 5° K	a = 5° Q	a = 6° K	a = 6° Q
°	° '	° '	° '	° '	° '	° '	° '	° '	° '	° '	° '	° '	° '	° '
0	0 0	0 0	0 0	1 0	0 0	2 0	0 0	3 0	0 0	4 0	0 0	5 0	0 0	6 0
1	1 0	0	1 0	0	1 0	0	1 0	0	1 0	0	1 0	0	1 0	0
2	2 0	0	2 0	0	2 0	0	2 0	0	2 0	0	2 0	0	59	0
3	3 0	0	3 0	0	3 0	0	3 0	0	3 0	0	59	0	2 59	0
4	4 0	0	4 0	0	4 0	0	4 0	0	59	1	3 59	1	3 59	1
5	5 0	0	5 0	0	5 0	0	5 0	1	4 59	1	4 59	1	4 58	1
6	6 0	0	6 0	0	6 0	1	6 0	1	5 59	1	5 59	2	5 58	2
7	7 0	0	7 0	0	7 0	1	59	1	6 59	2	6 58	2	6 58	3
8	8 0	0	8 0	1	8 0	1	7 59	2	7 59	2	7 58	3	7 57	4
9	9 0	0	9 0	1	9 0	1	8 59	2	8 59	3	8 58	4	8 57	5
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12	12 0	0	12 0	1	12 0	3	11 59	4	11 58	5	11 57	7	11 56	8
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19	19 0	0	19 0	3	18 59	7	18 58	10	18 57	14	18 55	17	18 54	21
20	20 0	0	20 0	4	19 59	8	19 58	11	19 57	15	19 55	19	19 53	23
21	21 0	0	21 0	4	20 59	9	20 58	13	20 57	17	20 55	21	20 53	25
22	22 0	0	22 0	5	21 59	9	21 58	14	21 57	19	21 55	23	21 52	28
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24	24 0	0	24 0	6	23 59	11	23 58	17	23 56	23	23 54	28	23 52	34
25	25 0	0	25 0	6	24 59	12	24 58	18	24 56	25	24 54	31	24 51	37
26	26 0	0	26 0	7	25 59	13	25 58	20	25 56	27	25 54	34	25 51	40
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44	44 0	0	59	23	43 58	47	43 55	10	43 52	33	43 47	56	43 42	19
45	45 0	0	44 59	25	44 58	50	44 55	14	44 52	39	44 47	7 3	44 41	27

b	a = 0°		a = 1°		a = 2°		a = 3°		a = 4°		a = 5°		a = 6°	
	K	Q	K	Q	K	Q	K	Q	K	Q	K	Q	K	Q
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
45	45 0	0 0	44 59	1 25	44 58	2 50	44 55	4 14	44 52	5 39	44 47	7 3	44 41	8 27
46	46 0	0	45 59	26	45 58	53	45 55	19	45 51	45	45 46	11	45 41	36
47	47 0	0	46 59	28	46 58	56	46 55	24	46 51	51	46 46	19	46 40	46
48	48 0	0	47 59	30	47 58	59	47 55	29	47 51	58	47 45	27	47 39	56
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50	50 0	0	49 59	33	49 58	7	49 54	40	49 50	13	49 44	45	49 38	17
51	51 0	0	50 59	35	50 57	11	50 54	46	50 50	21	50 44	55	50 37	29
52	52 0	0	51 59	37	51 57	15	51 54	52	51 49	29	51 43	8 5	51 36	41
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60	60 0	0	59 59	2 0	59 56	4 0	59 52	59	59 46	58	59 37	56	59 28	52
61	61 0	0	60 59	4	60 56	7	60 52	6 10	60 45	8 13	60 36	10 14	60 26	12 14
62	62 0	0	61 59	8	61 56	15	61 51	22	61 44	28	61 35	33	61 25	37
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65	65 0	0	64 59	22	64 56	43	64 50	7 4	64 42	24	64 32	42	64 20	58
66	66 0	0	65 59	27	65 55	54	65 49	20	65 41	45	65 31	12 8	65 18	14 29
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77	77 0	0	76 58	26	76 51	50	76 40	13 7	76 25	17 16	76 5	21 15	75 42	25 3
78	78 0	0	77 58	48	77 50	9 32	77 38	14 9	77 22	18 35	77 1	22 49	76 36	26 49
79	79 0	0	78 57	5 14	78 49	10 22	78 36	15 22	78 18	20 8	56	24 38	77 29	28 51
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89	89 0	0	88 35	45 0	46	63 27	50	71 35	53	75 59	54	78 43	55	80 34
90	90 0	0	89 0	90 0	88 0	90 0	87 0	90 0	86 0	90 0	85 0	90 0	84 0	90 0

b	a = 7°		a = 8°		a = 9°		a = 10°		a = 11°		a = 12°		a = 13°	
	K	Q	K	Q	K	Q	K	Q	K	Q	K	Q	K	Q
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
0	0 0	7 0	0 0	8 0	0 0	9 0	0 0	10 0	0 0	11 0	0 0	12 0	0 0	13 0
1	1 0	0	59	0	59	0	59	0	59	0	59	0	58	0
2	59	0	1 59	0	1 59	0	1 58	0	1 58	0	1 57	0	1 57	0
3	2 59	1	2 58	1	2 58	1	2 57	1	2 57	1	2 56	1	2 55	1
4	3 58	1	3 58	1	3 57	1	3 56	1	3 56	2	3 55	2	3 54	2
5	4 58	2	4 57	2	4 56	2	4 55	2	4 54	3	4 53	3	4 52	3
6	5 57	2	5 56	3	5 56	3	5 55	3	5 53	4	5 52	4	5 51	4
7	6 57	3	6 56	4	6 55	4	6 54	4	6 52	5	6 51	5	6 49	6
8	7 56	4	7 55	5	7 54	5	7 53	6	7 51	6	7 49	7	7 48	8
9	8 56	5	8 55	6	8 53	7	8 52	7	8 50	8	8 48	9	8 46	10
10	9 55	6	9 54	7	9 53	8	9 51	9	9 49	10	9 47	11	9 44	12
11	10 55	8	10 53	9	10 52	10	10 50	11	10 48	12	10 45	13	10 43	14
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16	15 53	17	15 50	19	15 48	21	15 45	24	15 42	26	15 38	28	15 35	30
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21	20 50	30	20 47	34	20 44	38	20 40	42	20 36	46	20 31	50	20 26	53
22	21 50	33	21 46	37	21 43	42	21 39	46	21 35	51	21 30	55	21 24	59
23	22 49	36	22 46	41	22 42	46	22 38	51	22 33	56	22 28	13 0	22 23	14 5
24	23 49	39	23 45	45	23 41	50	23 37	56	23 32	12 1	23 27	6	23 21	11
25	24 48	43	24 44	49	24 40	55	24 36	11 1	24 31	6	24 25	12	24 19	17
26	25 48	47	25 44	53	25 39	10 0	25 35	6	25 29	12	25 23	18	25 17	24
27	26 47	51	26 43	58	26 38	5	26 33	12	26 28	18	26 22	25	26 15	31
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31	30 45	9	30 40	19	30 35	28	30 29	38	30 22	47	30 15	56	30 7	15 5
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b	a = 7° K	a = 7° Q	a = 8° K	a = 8° Q	a = 9° K	a = 9° Q	a = 10° K	a = 10° Q	a = 11° K	a = 11° Q	a = 12° K	a = 12° Q	a = 13° K	a = 13° Q
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
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81	78 37	38 8	59	41 56	77 18	45 21	76 35	48 25	49	51 10	75 2	53 39	74 14	55 53
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83	80 7	45 13	79 23	49 4	78 37	52 25	49	55 21	59	57 55	76 8	60 10	75 16	62 10
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85	81 24	54 38	35	58 12	43	61 11	50	63 42	56	65 51	77 1	67 42	76 5	69 19
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89	56	81 55	56	82 55	57	83 43	57	84 21	57	84 52	58	85 18	58	85 41
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b	a = 14° K	a = 14° Q	a = 15° K	a = 15° Q	a = 16° K	a = 16° Q	a = 17° K	a = 17° Q	a = 18° K	a = 18° Q	a = 19° K	a = 19° Q	a = 20° K	a = 20° Q
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
0	0 0	14 0	0 0	15 0	0 0	16 0	0 0	17 0	0 0	18 0	0 0	19 0	0 0	20 0
1	58	0	58	0	58	0	57	0	57	0	57	0	56	0
2	1 56	0	1 56	1	1 55	1	1 55	1	1 54	1	1 54	1	1 53	1
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6	5 49	4	5 48	5	5 46	5	5 44	5	5 42	6	5 40	6	5 38	6
7	6 47	6	6 46	7	6 44	7	6 42	7	6 39	8	6 37	8	6 35	8
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9	8 44	10	8 41	11	8 39	11	8 36	12	8 33	13	8 30	13	8 27	14
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b	K	Q	K	Q	K	Q	K	Q	K	Q	K	Q	K	Q
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
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86	27	74 22	29	75 25	31	76 20	33	77 9	35	77 53	36	78 33	37	79 9
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88	52	82 2	52	82 35	53	83 4	53	83 29	54	83 52	54	84 13	54	84 31
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b	a = 21°		a = 22°		a = 23°		a = 24°		a = 25°		a = 26°		a = 27°	
	K	Q	K	Q	K	Q	K	Q	K	Q	K	Q	K	Q
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
0	0 0	21 0	0 0	22 0	0 0	23 0	0 0	24 0	0 0	25 0	0 0	26 0	0 0	27 0
1	56	0	56	0	55	0	55	0	54	0	54	0	53	0
2	1 52	1	1 51	1	1 51	1	1 50	1	1 49	1	1 48	1	1 47	1
3	2 48	2	2 47	2	2 46	2	2 44	2	2 43	2	2 42	2	2 40	2
4	3 44	3	3 42	3	3 41	3	3 39	3	3 38	3	3 36	3	3 34	3
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16	14 55	46	14 48	48	14 42	49	14 35	51	14 28	53	14 21	54	14 13	56
17	15 50	52	15 44	54	15 37	56	15 29	58	15 22	26 0	15 14	27 1	15 6	28 3
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21	19 33	21	19 24	24	19 16	27	19 7	30	57	32	18 47	35	18 37	37
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23	21 24	38	21 14	42	21 5	45	55	49	20 44	52	20 33	55	20 22	58
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25	23 14	57	23 4	24 2	22 54	25 6	22 43	26 10	22 31	14	22 19	17	22 7	21
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b	a = 21°		a = 22°		a = 23°		a = 24°		a = 25°		a = 26°		a = 27°	
	K	Q	K	Q	K	Q	K	Q	K	Q	K	Q	K	Q
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
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b	a = 28°		a = 29°		a = 30°		a = 31°		a = 32°		a = 33°		a = 34°	
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°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
0	0 0	28 0	0 0	29 0	0 0	30 0	0 0	31 0	0 0	32 0	0 0	33 0	0 0	34 0
1	53	0	52	0	52	0	51	0	51	0	50	0	50	0
2	1 46	1	1 45	1	1 44	1	1 43	1	1 42	1	1 41	1	1 39	1
3	2 39	2	2 37	2	2 36	2	2 34	2	2 33	2	2 31	2	2 29	2
4	3 32	3	3 30	4	3 28	4	3 26	4	3 23	4	3 21	4	3 19	4
5	4 25	5	4 22	6	4 20	6	4 17	6	4 14	6	4 12	6	4 9	6
6	5 18	8	5 15	8	5 12	8	5 8	8	5 5	8	5 2	9	58	9
7	6 11	11	6 7	11	6 4	11	6 0	11	56	11	52	12	5 48	12
8	7 4	14	59	14	55	15	51	15	6 47	15	6 42	15	6 38	16
9	56	18	7 52	18	7 47	19	7 43	19	7 37	19	7 32	19	7 27	20
10	8 49	22	8 44	22	8 39	23	8 34	23	8 28	24	8 22	24	8 17	25
11	9 42	27	9 36	27	9 31	28	9 25	28	9 19	29	9 12	29	9 6	30
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13	11 27	37	11 21	38	11 14	39	11 7	40	11 0	40	52	41	10 45	41
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20	17 35	30	17 24	32	17 14	34	17 3	36	52	37	16 40	39	16 28	40
21	18 27	40	18 16	42	18 5	44	53	46	17 42	48	17 29	49	17 17	51
22	19 19	50	19 8	52	56	55	18 44	57	18 31	59	18 19	35 0	18 6	36 2
23	20 11	30 1	59	31 3	19 47	32 6	19 34	33 8	19 21	34 10	19 8	12	54	14
24	21 3	12	20 50	15	20 37	18	20 24	20	20 11	22	57	24	19 42	26
25	55	24	21 41	27	21 28	30	21 14	33	21 0	35	20 46	37	20 30	39
26	22 46	37	22 32	40	22 19	43	22 4	46	49	48	21 34	51	21 18	53
27	23 38	50	23 23	53	23 9	57	54	34 0	22 38	35 2	22 23	36 5	22 6	37 8
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31	27 3	49	26 47	53	26 29	58	26 12	35 2	54	36 6	25 35	37 9	25 16	38 12
32	54	32 5	27 37	33 10	27 19	34 15	27 1	19	26 42	23	26 23	27	26 3	30
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38	56	34 1	32 35	35 7	32 13	36 14	51	37 20	31 28	25	31 5	30	30 42	34
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41	35 24	35 10	35 1	36 18	34 37	25	34 13	31	48	37	33 23	43	57	47
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43	37 2	36 1	36 37	37 10	36 12	38 17	46	39 24	35 20	31	53	36	34 26	41
44	50	28	37 25	37	59	45	36 33	52	36 6	59	35 38	42 5	35 10	43 10
45	38 38	57	38 12	38 5	37 46	39 14	37 19	40 21	51	41 28	36 22	34	53	39

b	a = 28°		a = 29°		a = 30°		a = 31°		a = 32°		a = 33°		a = 34°	
	K	Q	K	Q	K	Q	K	Q	K	Q	K	Q	K	Q
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
45	38 38	36 57	38 12	38 5	37 46	39 14	37 19	40 21	36 51	41 28	36 22	42 34	35 53	43 39
46	39 26	37 26	59	35	38 32	44	38 4	52	37 36	58	37 6	43 4	36 36	44 9
47	40 13	56	39 46	39 6	39 18	40 15	49	41 23	38 20	42 30	50	36	37 19	41
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49	47	39 1	41 18	40 11	49	41 21	40 19	42 29	48	36	39 16	43	44	48
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52	44 5	49	43 34	42 0	43 2	43 10	42 29	44 18	56	45 26	41 22	46 32	48	47 37
53	50	41 28	44 18	39	46	49	43 12	57	42 38	46 5	42 3	47 11	41 28	48 16
54	45 35	42 8	45 2	43 19	44 29	44 29	54	45 38	43 19	45	44	51	42 7	56
55	46 19	50	46	44 1	45 11	45 11	44 36	46 20	44 0	47 27	43 24	48 33	46	49 37
56	47 3	43 34	46 29	45	53	55	45 17	47 4	40	48 10	44 3	49 16	43 25	50 20
57	46	44 19	47 11	45 30	46 35	46 40	58	49	45 20	55	42	50 1	44 3	51 5
58	48 29	45 6	53	46 17	47 16	47 27	46 38	48 35	59	49 42	45 20	47	40	51
59	49 11	55	48 34	47 6	56	48 16	47 17	49 24	46 38	50 30	58	51 35	45 17	52 38
60	52	46 46	49 14	57	48 36	49 6	56	50 14	47 16	51 20	46 35	52 24	53	53 27
61	50 33	47 38	54	48 50	49 15	59	48 34	51 6	53	52 12	47 11	53 15	46 28	54 18
62	51 13	48 33	50 33	49 44	53	50 53	49 11	52 0	48 29	53 5	46	54 8	47 3	55 10
63	53	49 30	51 12	50 41	50 30	51 49	48	56	49 5	54 0	48 21	55 3	37	56 4
64	52 31	50 30	49	51 40	51 7	52 48	50 24	53 53	40	57	55	59	48 10	59
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66	46	52 35	53 2	53 44	52 18	54 50	51 33	55 55	47	56 56	50 1	57 57	49 14	58 55
67	54 22	53 41	37	54 49	52	55 55	52 6	56 58	51 19	57 59	32	58 58	44	59 55
68	57	54 50	54 11	55 57	53 25	57 1	38	58 3	50	59 4	51 2	60 1	50 14	60 57
69	55 31	56 1	44	57 7	57	58 10	53 9	59 11	52 21	60 10	32	61 6	43	62 1
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71	36	58 31	47	59 34	58	60 35	54 8	61 33	53 18	62 29	28	63 22	37	64 14
72	57 7	59 50	56 17	60 52	55 27	61 51	36	62 47	45	63 41	54	64 33	52 3	65 23
73	36	61 12	46	62 12	55	63 9	55 3	64 3	54 11	64 56	53 19	65 46	27	66 34
74	58 4	62 36	57 13	63 34	56 21	64 29	29	65 21	36	66 12	43	67 0	50	67 46
75	31	64 3	39	64 58	46	65 51	53	66 42	55 0	67 30	54 6	68 16	53 12	69 0
76	57	65 32	58 4	66 25	57 10	67 16	56 16	68 4	22	68 50	28	69 34	33	70 16
77	59 21	67 4	27	67 54	33	68 43	38	69 29	43	70 12	48	70 54	53	71 33
78	44	68 39	49	69 26	54	70 12	58	70 55	56 3	71 36	55 7	72 15	54 11	72 52
79	60 5	70 16	59 9	71 0	58 13	71 43	57 17	72 23	21	73 1	25	73 38	28	74 12
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82	58	75 20	60 0	75 54	59 3	76 27	58 5	76 57	57 7	77 27	56 9	77 54	55 11	78 21
83	61 12	77 6	14	77 36	16	78 5	18	78 32	19	78 58	21	79 22	22	79 46
84	25	78 53	26	79 19	28	79 44	29	80 8	30	80 30	31	80 51	32	81 12
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86	44	82 32	45	82 50	46	83 7	46	83 23	47	83 38	47	83 52	48	84 6
87	51	84 23	51	84 36	52	84 49	52	85 1	53	85 13	53	85 23	53	85 34
88	56	86 15	56	86 24	56	86 32	56	86 40	57	86 48	57	86 55	57	87 2
89	59	88 7	59	88 12	59	88 16	59	88 20	59	88 24	59	88 27	59	88 31
90	62 0	90 0	61 0	90 0	60 0	90 0	59 0	90 0	58 0	90 0	57 0	90 0	56 0	90 0

b	a = 35° K	a = 35° Q	a = 36° K	a = 36° Q	a = 37° K	a = 37° Q	a = 38° K	a = 38° Q	a = 39° K	a = 39° Q	a = 40° K	a = 40° Q	a = 41° K	a = 41° Q
°	° ′	° ′	° ′	′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
0	0 0	35 0	0 0	36 0	0 0	37 0	0 0	38 0	0 0	39 0	0 0	40 0	0 0	41 0
1	49	0	49	0	48	0	47	0	47	0	46	0	45	0
2	1 38	1	1 37	1	1 36	1	1 35	1	1 33	1	1 32	1	1 31	1
3	2 27	2	2 26	2	2 24	2	2 22	2	2 20	2	2 18	2	2 16	2
4	3 17	4	3 14	4	3 12	4	3 9	4	3 7	4	3 4	4	3 1	4
5	4 6	6	4 3	6	59	6	56	6	53	6	50	6	46	6
6	55	9	51	9	4 47	9	4 44	9	4 40	9	4 36	9	4 31	9
7	5 44	12	5 39	12	5 35	12	5 31	12	5 26	13	5 21	13	5 17	13
8	6 33	16	6 28	16	6 23	16	6 18	16	6 13	17	6 7	17	6 2	17
9	7 22	20	7 16	20	7 11	20	7 5	21	59	21	53	21	47	21
10	8 11	25	8 5	25	58	25	52	26	7 45	26	7 39	26	7 32	26
11	9 0	30	53	30	8 46	31	8 39	31	8 32	31	8 24	31	8 17	32
12	48	36	9 41	36	9 34	37	9 26	37	9 18	37	9 10	37	9 2	38
13	10 37	42	10 29	43	10 21	43	10 13	43	10 4	44	55	44	47	44
14	11 26	49	11 17	50	11 8	50	59	50	50	51	10 41	51	10 31	51
15	12 14	56	12 5	57	56	57	11 46	58	11 36	59	11 26	59	11 16	59
16	13 3	36 4	53	37 5	12 43	38 5	12 33	39 6	12 22	40 7	12 11	41 7	12 0	42 7
17	51	13	13 41	13	13 30	14	13 19	15	13 8	16	56	16	45	16
18	14 40	22	14 29	22	14 17	23	14 6	24	54	25	13 41	25	13 29	26
19	15 28	31	15 16	32	15 4	33	52	34	14 40	35	14 26	35	14 13	36
20	16 16	41	16 4	43	51	44	15 38	44	15 25	45	15 11	46	57	46
21	17 4	52	51	54	16 38	55	16 24	55	16 10	56	56	57	15 41	57
22	52	37 4	17 38	38 5	17 25	39 6	17 10	40 7	55	41 8	16 41	42 9	16 25	43 9
23	18 40	16	18 25	17	18 11	18	56	19	17 40	20	17 25	21	17 9	22
24	19 28	28	19 12	30	57	31	18 42	32	18 25	33	18 9	34	53	35
25	20 15	41	59	43	19 43	45	19 27	46	19 10	47	53	48	18 36	48
26	21 3	55	20 46	57	20 29	59	20 13	41 0	55	42 1	19 37	43 2	19 19	44 3
27	50	38 10	21 33	39 12	21 15	40 13	58	15	20 40	16	20 21	17	20 2	18
28	22 37	25	22 19	27	22 1	29	21 43	30	21 24	32	21 5	33	45	33
29	23 24	41	23 5	43	47	45	22 28	46	22 8	48	48	49	21 28	49
30	24 11	57	51	40 0	23 32	41 2	23 12	42 3	52	43 5	22 31	44 6	22 10	45 6
31	57	39 15	24 37	17	24 17	19	57	21	23 36	22	23 14	23	52	24
32	25 44	33	25 23	35	25 2	37	24 41	39	24 19	41	57	42	23 34	43
33	26 30	52	26 9	54	47	56	25 25	58	25 2	44 0	24 40	45 1	24 16	46 2
34	27 16	40 11	54	41 14	26 32	42 16	26 9	43 18	45	20	25 22	21	58	22
35	28 2	31	27 39	34	27 16	37	52	39	26 28	40	26 4	41	25 39	42
36	47	52	28 24	56	28 0	58	27 35	44 0	27 11	45 2	46	46 3	26 20	47 3
37	29 32	41 14	29 8	42 18	44	43 20	28 18	22	53	24	27 27	25	27 1	25
38	30 17	37	52	41	29 27	43	29 1	45	28 35	47	28 8	48	41	48
39	31 2	42 1	30 36	43 4	30 10	44 7	44	45 9	29 17	46 11	49	47 12	28 21	48 12
40	46	26	31 20	29	53	32	30 26	34	58	35	29 30	36	29 1	37
41	32 30	51	32 3	55	31 36	58	31 8	46 0	30 39	47 1	30 10	48 2	41	49 2
42	33 14	43 18	46	44 21	32 18	45 24	49	26	31 20	28	50	28	30 20	28
43	58	45	33 29	49	33 0	52	32 30	53	32 0	55	31 30	55	59	55
44	34 41	44 14	34 12	45 17	42	46 20	33 11	47 22	40	48 23	32 9	49 24	31 37	50 23
45	35 24	43	54	46	34 23	49	52	51	33 20	52	48	53	32 15	52

b	a = 35°		a = 36°		a = 37°		a = 38°		a = 39°		a = 40°		a = 41°	
	K	Q	K	Q	K	Q	K	Q	K	Q	K	Q	K	Q
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
45	35 24	44 43	34 54	45 46	34 23	46 49	33 52	47 51	33 20	48 52	32 48	49 53	32 15	50 52
46	36 6	45 14	35 35	46 17	35 4	47 20	34 32	48 22	59	49 23	33 26	50 23	53	51 22
47	48	45	36 16	49	44	51	35 12	53	34 38	54	34 4	54	33 30	53
48	37 30	46 18	57	47 21	36 24	48 24	51	49 25	35 17	50 26	42	51 26	34 7	52 25
49	38 11	52	37 38	55	37 4	57	36 30	59	55	59	35 19	59	43	57
50	52	47 27	38 18	48 30	43	49 32	37 8	50 33	36 32	51 33	56	52 33	35 19	53 31
51	39 32	48 3	57	49 6	38 22	50 8	46	51 9	37 9	52 9	36 32	53 8	55	54 6
52	40 12	41	39 36	43	39 0	45	38 23	46	46	45	37 8	44	36 30	42
53	52	49 19	40 15	50 22	38	51 23	39 0	52 24	38 22	53 23	43	54 21	37 4	55 18
54	41 31	59	53	51 2	40 15	52 3	36	53 3	57	54 2	38 18	59	38	56
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57	43 24	52 7	43	53 9	42 3	54 8	41 22	55 7	41	56 4	59	57 1	39 16	56
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61	46	55 18	45 2	56 17	44 19	57 15	34	58 11	49	59 6	42 4	59	41 18	51
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63	53	57 3	46 7	58 0	45 22	56	36	50	50	60 43	43 3	61 35	42 15	62 25
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68	49 25	61 51	36	62 44	46	63 34	56	64 23	46 6	65 11	45 16	57	24	66 41
69	53	62 54	49 3	63 45	48 13	64 34	47 22	65 22	31	66 8	40	66 53	48	67 36
70	50 20	63 58	29	64 48	38	65 35	46	66 22	55	67 6	46 3	67 50	45 10	68 31
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76	38	70 56	43	71 35	48	72 12	52	72 48	57	73 22	48 1	73 55	47 5	74 27
77	57	72 11	52 1	72 48	51 6	73 23	50 9	73 56	49 13	74 29	17	75 0	20	75 30
78	53 15	73 28	18	74 2	22	74 35	25	75 6	29	75 36	32	76 5	35	76 33
79	31	74 45	34	75 17	37	75 47	40	76 17	43	76 45	46	77 11	48	77 37
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81	54 0	77 24	53 2	77 51	52 4	78 16	51 6	78 41	50 8	79 4	49 10	79 26	12	79 48
82	13	78 46	14	79 9	16	79 32	17	79 54	19	80 15	20	80 35	22	80 54
83	24	80 8	25	80 29	26	80 49	27	81 8	29	81 27	29	81 44	31	82 1
84	33	81 31	34	81 49	35	82 6	36	82 23	37	82 39	37	82 54	39	83 9
85	41	82 54	42	83 10	43	83 24	43	83 38	44	83 52	44	84 4	45	84 17
86	48	84 19	49	84 31	49	84 43	49	84 54	50	85 5	50	85 15	50	85 25
87	53	85 44	54	85 53	54	86 2	54	86 10	54	86 18	54	86 26	54	86 33
88	57	87 9	57	87 15	57	87 21	57	87 26	57	87 32	57	87 37	57	87 42
89	59	88 34	59	88 37	59	88 40	59	88 43	59	88 46	59	88 48	59	88 51
90	55 0	90 0	54 0	90 0	53 0	90 0	52 0	90 0	51 0	90 0	50 0	90 0	49 0	90 0

b	a = 42°		a = 43°		a = 44°		a = 45°		a = 46°		a = 47°		a = 48°	
	K	Q	K	Q	K	Q	K	Q	K	Q	K	Q	K	Q
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
0	0 0	42 0	0 0	43 0	0 0	44 0	0 0	45 0	0 0	46 0	0 0	47 0	0 0	48 0
1	45	0	44	0	43	0	42	0	42	0	41	0	40	0
2	1 29	1	1 28	1	1 26	1	1 25	1	1 23	1	1 22	1	1 20	1
3	2 14	2	2 12	2	2 10	2	2 7	2	2 5	2	2 3	2	2 0	2
4	58	4	55	4	53	4	50	4	47	4	44	4	40	4
5	3 43	6	3 39	6	3 36	6	3 32	6	3 28	6	3 25	6	3 20	6
6	4 27	9	4 23	9	4 19	9	4 14	9	4 10	9	4 5	9	4 0	9
7	5 12	13	5 7	13	5 2	13	57	13	51	13	46	13	40	13
8	56	17	51	17	45	17	5 39	17	5 33	17	5 27	17	5 20	17
9	6 41	21	6 34	21	6 28	21	6 21	21	6 14	21	6 7	21	6 0	21
10	7 25	26	7 18	26	7 11	26	7 3	26	56	26	48	26	40	26
11	8 9	32	8 1	32	53	32	45	32	7 37	32	7 29	32	7 20	32
12	53	38	45	38	8 36	38	8 27	38	8 18	38	8 9	38	8 0	38
13	9 37	45	9 28	45	9 19	45	9 9	45	59	45	49	45	39	44
14	10 21	52	10 11	52	10 1	52	51	52	9 40	52	9 30	52	9 19	51
15	11 5	59	55	44 0	44	45 0	10 33	46 0	10 21	47 0	10 10	48 0	58	59
16	49	43 8	11 38	8	11 26	8	11 15	8	11 2	8	50	8	10 38	49 7
17	12 33	17	12 21	17	12 8	17	56	17	43	17	11 30	17	11 17	16
18	13 17	26	13 4	26	50	26	12 37	26	12 24	26	12 10	26	56	25
19	14 0	36	46	36	13 32	36	13 18	36	13 4	36	50	36	12 35	35
20	44	47	14 29	47	14 14	47	59	47	45	47	13 29	46	13 14	46
21	15 27	58	15 12	58	56	58	14 40	58	14 25	58	14 9	57	53	57
22	16 10	44 10	54	45 10	15 38	46 10	15 21	47 10	15 5	48 10	48	49 9	14 31	50 9
23	53	22	16 36	22	16 19	22	16 2	22	45	22	15 27	21	15 9	21
24	17 36	35	17 18	35	17 1	35	43	35	16 25	35	16 6	34	47	34
25	18 19	49	18 0	49	42	49	17 23	49	17 5	49	45	48	16 25	47
26	19 1	45 3	42	46 3	18 23	47 3	18 3	48 3	44	49 3	17 24	50 2	17 3	51 1
27	43	18	19 24	18	19 4	18	43	18	18 23	17	18 2	17	41	16
28	20 25	34	20 5	34	44	34	19 23	33	19 2	33	40	32	18 19	31
29	21 7	50	46	50	20 25	50	20 3	49	41	49	19 18	48	56	47
30	49	46 7	21 27	47 7	21 5	48 7	42	49 6	20 20	50 6	56	51 5	19 33	52 3
31	22 30	25	22 8	25	45	25	21 21	24	58	23	20 34	22	20 10	20
32	23 11	43	48	43	22 25	43	22 0	42	21 36	41	21 11	40	46	38
33	52	47 2	23 28	48 2	23 4	49 2	39	50 1	22 14	51 0	48	58	21 22	56
34	24 33	22	24 8	22	43	21	23 18	20	52	19	22 25	52 17	58	53 15
35	25 14	42	48	42	24 22	42	56	41	23 29	39	23 2	37	22 34	35
36	54	48 4	25 28	49 3	25 1	50 3	24 34	51 2	24 6	52 0	38	58	23 10	56
37	26 34	26	26 7	25	39	25	25 11	23	43	22	24 14	53 19	45	54 17
38	27 14	49	46	48	26 17	47	48	46	25 19	44	50	41	24 20	39
39	53	49 12	27 24	50 12	55	51 11	26 25	52 9	55	53 7	25 25	54 4	54	55 1
40	28 32	37	28 2	36	27 32	35	27 2	33	26 31	31	26 0	28	25 28	24
41	29 11	50 2	40	51 1	28 9	52 0	38	58	27 7	55	35	52	26 2	48
42	49	28	29 18	27	46	25	28 14	53 23	42	54 20	27 9	55 17	36	56 13
43	30 27	55	55	54	29 23	52	50	49	28 17	46	43	42	27 9	38
44	31 5	51 23	30 32	52 21	59	53 19	29 25	54 16	51	55 13	28 17	56 9	42	57 4
45	42	51	31 9	50	30 34	47	30 0	44	29 25	40	50	36	28 14	31

b	a = 42° K	a = 42° Q	a = 43° K	a = 43° Q	a = 44° K	a = 44° Q	a = 45° K	a = 45° Q	a = 46° K	a = 46° Q	a = 47° K	a = 47° Q	a = 48° K	a = 48° Q
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
45	31 42	51 51	31 9	52 50	30 34	53 47	30 0	54 44	29 25	55 40	28 50	56 36	28 14	57 31
46	32 19	52 21	45	53 19	31 10	54 16	34	55 13	59	56 9	29 23	57 4	46	59
47	55	52	32 20	49	45	46	31 8	42	30 32	38	55	33	29 18	58 27
48	33 31	53 23	55	54 20	32 19	55 17	42	56 13	31 5	57 8	30 27	58 2	49	56
49	34 7	55	33 30	52	53	49	32 15	44	37	39	59	33	30 20	59 26
50	42	54 29	34 4	55 25	33 26	56 21	48	57 16	32 9	58 10	31 30	59 4	50	56
51	35 17	55 3	38	59	59	55	33 20	49	40	43	32 0	36	31 20	60 28
52	51	38	35 11	56 34	34 32	57 29	52	58 23	33 11	59 16	30	60 8	49	61 0
53	36 24	56 15	44	57 10	35 4	58 4	34 23	58	42	50	33 0	42	32 18	33
54	57	52	36 17	47	35	40	54	59 33	34 12	60 25	29	61 16	46	62 7
55	37 30	57 30	48	58 24	36 6	59 17	35 24	60 10	41	61 1	58	52	33 14	41
56	38 2	58 9	37 19	59 3	36	56	53	47	35 10	38	34 26	62 28	41	63 17
57	33	50	50	43	37 6	60 35	36 22	61 26	38	62 15	53	63 4	34 8	53
58	39 4	59 31	38 20	60 24	35	61 15	51	62 5	36 6	54	35 20	42	34	64 30
59	34	60 14	49	61 5	38 4	56	37 19	45	33	63 33	46	64 21	35 0	65 7
60	40 4	57	39 18	48	32	62 38	46	63 26	59	64 14	36 12	65 0	25	46
61	33	61 42	46	62 32	59	63 21	38 12	64 8	37 25	55	37	40	49	66 25
62	41 1	62 28	40 13	63 17	39 26	64 4	38	51	50	65 37	37 1	66 21	36 13	67 5
63	28	63 15	40	64 2	52	49	39 3	65 35	38 14	66 20	25	67 3	36	46
64	54	64 2	41 6	49	40 17	65 35	27	66 20	38	67 3	48	46	58	68 28
65	42 20	51	31	65 37	41	66 22	51	67 5	39 1	48	38 10	68 30	37 20	69 10
66	45	65 41	55	66 26	41 5	67 10	40 14	52	23	68 33	32	69 14	41	53
67	43 10	66 32	42 19	67 16	28	58	36	68 40	45	69 20	53	59	38 1	70 37
68	33	67 25	42	68 7	50	68 48	58	69 28	40 6	70 7	39 13	70 45	21	71 22
69	56	68 18	43 4	59	42 11	69 38	41 19	70 17	26	55	33	71 31	40	72 7
70	44 18	69 12	25	69 52	31	70 30	39	71 7	45	71 43	51	72 19	58	53
71	39	70 7	45	70 45	51	71 22	58	58	41 3	72 33	40 9	73 7	39 15	73 40
72	59	71 3	44 4	71 40	43 10	72 15	42 16	72 50	21	73 23	26	56	31	74 27
73	45 18	72 1	22	72 36	28	73 9	33	73 42	38	74 14	42	74 45	47	75 15
74	36	59	40	73 32	45	74 4	49	74 35	54	75 6	58	75 35	40 2	76 4
75	53	73 58	57	74 29	44 1	75 0	43 5	75 29	42 9	58	41 12	76 26	16	53
76	46 9	74 58	45 12	75 27	16	56	19	76 24	23	76 51	26	77 17	29	77 43
77	24	75 58	27	76 26	30	76 53	33	77 19	36	77 45	39	78 9	41	78 33
78	38	77 0	41	77 26	43	77 51	46	78 15	48	78 39	51	79 2	53	79 24
79	51	78 2	53	78 26	55	78 49	57	79 12	43 0	79 34	42 2	55	41 3	80 15
80	47 3	79 5	46 5	79 27	45 6	79 48	44 8	80 9	10	80 29	12	80 48	13	81 7
81	13	80 9	15	80 29	16	80 48	18	81 7	20	81 25	21	81 42	22	59
82	23	81 13	24	81 31	26	81 48	27	82 5	28	82 21	29	82 36	30	82 52
83	32	82 18	32	82 33	34	82 48	34	83 3	35	83 17	36	83 31	37	83 45
84	39	83 23	40	83 36	41	83 49	41	84 2	42	84 14	42	84 26	43	84 38
85	46	84 28	46	84 39	47	84 50	47	85 1	47	85 11	48	85 21	48	85 31
86	51	85 34	51	85 43	51	85 52	52	86 0	52	86 9	52	86 17	52	86 24
87	55	86 40	55	86 47	55	86 54	55	87 0	55	87 6	56	87 12	56	87 18
88	58	87 47	58	87 51	58	87 56	58	88 0	58	88 4	58	88 8	58	88 12
89	59	88 53	59	88 56	59	88 58	59	89 0	59	89 2	43 0	89 4	42 0	89 6
90	48 0	90 0	47 0	90 0	46 0	90 0	45 0	90 0	44 0	90 0	0	90 0	0	90 0

b	a = 49°		a = 50°		a = 51°		a = 52°		a = 53°		a = 54°		a = 55°	
	K	Q	K	Q	K	Q	K	Q	K	Q	K	Q	K	Q
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
0	0 0	49 0	0 0	50 0	0 0	51 0	0 0	52 0	0 0	53 0	0 0	54 0	0 0	55 0
1	39	0	39	0	38	0	37	0	36	0	35	0	34	0
2	1 19	1	1 17	1	1 16	1	1 14	1	1 12	1	1 11	1	1 9	1
3	58	2	56	2	53	2	51	2	48	2	46	2	43	2
4	2 37	4	2 34	4	2 31	4	2 28	4	2 24	4	2 21	4	2 18	4
5	3 17	6	3 13	6	3 9	6	3 5	6	3 0	6	56	6	52	6
6	56	9	51	9	47	9	41	9	36	9	3 31	9	3 26	9
7	4 35	13	4 30	13	4 24	13	4 18	12	4 12	12	4 6	12	4 0	12
8	5 14	17	5 8	17	5 2	17	55	16	48	16	41	16	35	16
9	53	21	46	21	39	21	5 32	21	5 24	20	5 16	20	5 9	20
10	6 32	26	6 25	26	6 16	26	6 8	26	6 0	25	51	25	43	25
11	7 11	32	7 3	31	54	31	45	31	36	30	6 26	30	6 17	30
12	50	38	41	37	7 31	37	7 21	37	7 11	36	7 1	36	51	36
13	8 29	44	8 19	44	8 8	44	58	43	47	43	36	42	7 25	42
14	9 8	51	57	51	45	51	8 34	50	8 22	50	8 11	49	59	49
15	47	59	9 35	59	9 22	58	9 10	58	58	57	45	56	8 32	56
16	10 25	50 7	10 12	51 7	59	52 6	46	53 6	9 33	54 5	9 19	55 4	9 6	56 3
17	11 4	16	50	15	10 36	15	10 22	14	10 8	13	54	12	39	11
18	42	25	11 28	24	11 13	24	58	23	43	22	10 28	21	10 13	20
19	12 20	35	12 5	34	49	34	11 34	33	11 18	32	11 2	31	46	29
20	58	45	42	45	12 26	44	12 9	43	53	42	36	41	11 19	39
21	13 36	56	13 19	56	13 2	55	45	54	12 27	52	12 10	51	52	49
22	14 14	51 8	56	52 7	38	53 6	13 20	54 5	13 2	55 3	43	56 2	12 25	57 0
23	51	20	14 33	19	14 14	18	55	17	36	15	13 17	14	57	12
24	15 29	33	15 9	32	50	30	14 30	29	14 10	27	50	26	13 30	24
25	16 6	46	46	45	15 26	43	15 5	42	44	40	14 23	38	14 2	36
26	43	52 0	16 22	59	16 1	57	40	55	15 18	53	56	51	34	49
27	17 20	14	58	53 13	36	54 11	16 14	55 9	51	56 7	15 29	57 5	15 6	58 2
28	56	29	17 34	28	17 11	26	48	24	16 25	22	16 1	19	37	16
29	18 33	45	18 10	44	46	42	17 22	39	58	37	33	34	16 9	31
30	19 9	53 2	45	54 0	18 20	58	56	55	17 31	52	17 5	49	40	46
31	45	19	19 20	17	55	55 14	18 29	56 11	18 3	57 8	37	58 5	17 11	59 2
32	20 21	36	55	34	19 29	31	19 2	28	36	25	18 9	22	42	18
33	56	54	20 30	52	20 3	49	35	46	19 8	42	40	39	18 12	35
34	21 31	54 13	21 4	55 11	37	56 7	20 8	57 4	40	58 0	19 11	56	42	52
35	22 6	33	38	30	21 10	26	41	23	20 12	19	42	59 14	19 12	60 10
36	41	53	22 12	50	43	46	21 13	42	43	38	20 13	33	42	28
37	23 15	55 14	46	56 10	22 16	57 7	45	58 2	21 14	58	43	52	20 12	47
38	49	35	23 19	32	48	28	22 17	23	45	59 18	21 13	60 12	41	61 7
39	24 23	57	52	54	23 20	49	48	44	22 15	39	43	33	21 10	27
40	57	56 20	24 24	57 16	52	58 11	23 19	59 6	45	60 0	22 12	54	38	48
41	25 30	44	56	39	24 23	34	50	29	23 15	22	41	61 16	22 6	62 9
42	26 3	57 8	25 28	58 3	54	58	24 20	52	45	45	23 10	38	34	31
43	35	33	26 0	28	25 25	59 22	50	60 15	24 14	61 8	38	62 1	23 2	53
44	27 7	59	31	53	55	47	25 19	40	43	32	24 6	25	29	63 16
45	38	58 25	27 2	59 19	26 25	60 12	48	61 5	25 11	57	34	49	56	40

b	a = 49° K	a = 49° Q	a = 50° K	a = 50° Q	a = 51° K	a = 51° Q	a = 52° K	a = 52° Q	a = 53° K	a = 53° Q	a = 54° K	a = 54° Q	a = 55° K	a = 55° Q
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
45	27 38	58 25	27 2	59 19	26 25	60 12	25 48	61 5	25 11	61 57	24 34	62 49	23 56	63 40
46	28 9	52	32	46	55	38	26 17	31	39	62 22	25 1	63 13	24 22	64 4
47	40	59 20	28 2	60 13	27 24	61 5	46	57	26 7	48	28	38	48	29
48	29 11	49	32	41	53	33	27 14	62 24	34	63 15	54	64 4	25 14	54
49	41	60 18	29 1	61 10	28 21	62 1	41	52	27 1	42	26 20	31	39	65 20
50	30 10	48	30	40	49	30	28 8	63 20	27	64 9	46	58	26 4	46
51	39	61 19	58	62 10	29 17	63 0	35	49	53	38	27 11	65 26	28	66 13
52	31 8	51	30 26	41	44	30	29 1	64 19	28 19	65 7	36	54	52	41
53	36	62 23	53	63 13	30 10	64 1	27	49	44	36	28 0	66 23	27 16	67 9
54	32 3	56	31 20	45	36	33	52	65 20	29 8	66 6	24	52	39	38
55	30	63 30	46	64 18	31 2	65 5	30 17	52	32	37	47	67 22	28 2	68 7
56	57	64 5	32 12	52	27	38	41	66 24	56	67 9	29 10	53	24	37
57	33 23	40	37	65 26	51	66 12	31 5	57	30 19	41	32	68 25	45	69 8
58	48	65 16	33 2	66 2	32 15	47	28	67 31	41	68 14	54	57	29 6	39
59	34 13	53	26	38	39	67 22	51	68 5	31 3	47	30 15	69 29	27	70 10
60	37	66 31	50	67 14	33 2	58	32 13	40	25	69 21	36	70 2	47	42
61	35 1	67 9	34 13	52	24	68 34	35	69 15	46	56	56	36	30 7	71 15
62	24	48	35	68 30	45	69 11	56	51	32 6	70 31	31 16	71 10	26	48
63	46	68 28	56	69 9	34 6	49	33 16	70 28	26	71 7	35	45	44	72 22
64	36 8	69 8	35 17	48	27	70 27	36	71 6	45	43	53	72 20	31 2	56
65	29	50	38	70 28	47	71 6	55	44	33 3	72 20	32 11	56	19	73 31
66	49	70 32	58	71 9	35 6	46	34 13	72 22	21	58	28	73 32	36	74 6
67	37 9	71 14	36 17	51	24	72 26	31	73 1	38	73 36	45	74 9	52	42
68	28	58	35	72 33	42	73 7	48	41	55	74 14	33 1	46	32 8	75 18
69	46	72 42	53	73 16	59	49	35 5	74 21	34 11	53	17	75 24	23	55
70	38 3	73 27	37 10	59	36 15	74 31	21	75 2	26	75 33	32	76 3	37	76 32
71	20	74 12	26	74 43	31	75 14	36	44	41	76 13	46	42	51	77 9
72	36	58	41	75 28	46	57	50	76 26	55	54	59	77 21	33 4	47
73	51	75 44	56	76 13	37 0	76 41	36 4	77 8	35 8	77 35	34 12	78 1	16	78 26
74	39 6	76 31	38 10	59	13	77 25	17	51	21	78 16	24	41	28	79 5
75	19	77 19	23	77 45	26	78 10	29	78 34	33	58	35	79 21	39	44
76	32	78 7	35	78 32	38	55	41	79 18	44	79 40	46	80 2	49	80 23
77	44	56	47	79 19	49	79 41	52	80 2	54	80 23	56	43	59	81 3
78	55	79 45	57	80 6	59	80 27	37 2	46	36 4	81 6	35 6	81 25	34 8	43
79	40 5	80 35	39 7	54	38 9	81 13	11	81 31	13	49	14	82 7	16	82 23
80	15	81 25	16	81 42	18	82 0	19	82 16	21	82 33	22	49	24	83 4
81	23	82 15	24	82 31	26	47	27	83 2	28	83 17	29	83 31	31	45
82	31	83 6	32	83 20	33	83 34	34	48	35	84 1	36	84 13	37	84 26
83	38	57	38	84 10	39	84 22	40	84 34	41	45	41	56	42	85 7
84	44	84 48	44	59	45	85 10	45	85 20	46	85 30	46	85 39	47	49
85	49	85 40	49	85 49	49	58	50	86 6	50	86 15	50	86 23	51	86 30
86	53	86 32	53	86 39	53	86 46	53	53	54	87 0	54	87 6	54	87 12
87	56	87 24	56	87 29	56	87 34	56	87 39	57	45	57	49	57	54
88	58	88 16	58	88 19	58	88 23	58	88 26	59	88 30	59	88 33	59	88 36
89	41 0	89 8	40 0	89 10	39 0	89 11	38 0	89 13	37 0	89 15	36 0	89 16	35 0	89 18
90	0	90 0	0	90 0	0	90 0	0	90 0	0	90 0	0	90 0	0	90 0

Table 13. Kelvin's Sumner Line Table

b	a = 56°		a = 57°		a = 58°		a = 59°		a = 60°		a = 61°		a = 62°	
	K	Q	K	Q	K	Q	K	Q	K	Q	K	Q	K	Q
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
0	0 0	56 0	0 0	57 0	0 0	58 0	0 0	59 0	0 0	60 0	0 0	61 0	0 0	62 0
1	34	0	33	0	32	0	31	0	30	0	29	0	28	0
2	1 7	1	1 5	1	1 4	1	1 2	1	1 0	1	58	1	56	1
3	41	2	38	2	35	2	33	2	30	2	1 27	2	1 25	2
4	2 14	4	2 11	4	2 7	4	2 4	4	2 0	4	56	4	53	3
5	48	6	43	6	39	6	34	6	30	6	2 25	6	2 21	5
6	3 21	9	3 16	9	3 11	8	3 5	8	3 0	8	54	8	49	8
7	54	12	48	12	42	11	36	11	30	11	3 23	11	3 17	11
8	4 28	16	4 21	15	4 14	15	4 7	15	59	14	52	14	45	14
9	5 1	20	53	19	45	19	37	19	4 29	18	4 21	18	4 13	18
10	34	24	5 26	24	5 17	24	5 8	23	59	23	50	22	41	22
11	6 7	29	58	29	48	29	38	28	5 29	28	5 19	27	5 8	26
12	40	35	6 30	35	6 20	34	6 9	33	58	33	47	32	36	31
13	7 13	41	7 2	41	51	40	39	39	6 28	38	6 16	38	6 4	37
14	46	48	34	47	7 22	46	7 9	45	57	44	44	44	31	43
15	8 19	55	8 6	54	53	53	39	52	7 26	51	7 13	50	59	49
16	52	57 3	38	58 2	8 24	59 0	8 9	59	55	58	41	57	7 26	56
17	9 25	11	9 10	10	55	8	39	60 7	8 24	61 6	8 9	62 4	53	63 3
18	57	19	42	18	9 26	17	9 9	15	53	14	37	12	8 20	11
19	10 29	28	10 13	27	56	26	39	24	9 22	22	9 5	20	47	19
20	11 1	38	44	36	10 27	35	10 9	33	51	31	33	29	9 14	27
21	33	48	11 15	46	57	45	38	43	10 19	40	10 0	38	41	36
22	12 5	59	46	57	11 27	55	11 7	53	48	50	28	48	10 8	45
23	37	58 10	12 17	59 8	57	60 6	36	61 3	11 16	62 1	55	58	34	55
24	13 9	22	48	19	12 27	17	12 5	14	44	12	11 22	63 9	11 0	64 5
25	40	34	13 19	31	57	29	34	26	12 12	23	49	20	26	16
26	14 11	47	49	44	13 26	41	13 3	38	40	35	12 16	31	52	27
27	42	59 0	14 19	57	55	54	31	50	13 7	47	43	43	12 18	39
28	15 13	14	49	60 10	14 24	61 7	59	62 3	34	59	13 9	55	44	51
29	44	28	15 19	24	53	21	14 27	17	14 1	63 12	36	64 8	13 9	65 4
30	16 14	43	48	39	15 22	35	55	31	28	26	14 2	21	34	17
31	44	58	16 17	54	50	50	15 23	45	55	40	28	35	59	30
32	17 14	60 14	46	61 10	16 18	62 5	50	63 0	15 22	55	53	49	14 24	44
33	44	30	17 15	26	46	21	16 17	15	48	64 10	15 19	65 4	49	58
34	18 13	47	44	42	17 14	37	44	31	16 14	25	44	19	15 13	66 13
35	42	61 5	18 12	59	42	54	17 11	48	40	41	16 9	35	37	28
36	19 11	23	40	62 17	18 9	63 11	37	64 5	17 6	58	34	51	16 1	44
37	40	41	19 8	35	36	29	18 3	22	31	65 15	58	66 7	25	67 0
38	20 8	62 0	36	54	19 3	47	29	40	56	32	17 22	24	48	16
39	36	20	20 3	63 13	29	64 6	55	58	18 21	50	46	42	17 11	33
40	21 4	40	30	33	55	25	19 20	65 17	45	66 8	18 10	67 0	34	50
41	31	63 1	56	53	20 21	45	45	36	19 9	27	33	18	56	68 8
42	58	23	21 22	64 14	46	65 5	20 10	56	33	47	56	37	18 18	26
43	22 25	45	48	36	21 11	26	34	66 17	56	67 7	19 19	56	40	45
44	51	64 7	22 14	58	36	48	58	38	20 19	27	41	68 16	19 2	69 4
45	23 17	30	39	65 20	22 0	66 10	21 22	59	42	48	20 3	36	23	24

b	a = 56°		a = 57°		a = 58°		a = 59°		a = 60°		a = 61°		a = 62°	
	K	Q	K	Q	K	Q	K	Q	K	Q	K	Q	K	Q
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
45	23 17	64 30	22 39	65 20	22 0	66 10	21 22	66 59	20 42	67 48	20 3	68 36	19 23	69 24
46	43	54	23 4	43	24	32	45	67 21	21 5	68 9	25	56	44	44
47	24 8	65 18	28	66 7	48	55	22 8	43	27	31	46	69 17	20 5	70 4
48	33	43	52	31	23 11	67 18	30	68 6	49	53	21 7	39	25	25
49	58	66 8	24 16	55	34	42	52	29	22 10	69 15	28	70 1	45	46
50	25 22	34	39	67 20	57	68 7	23 14	53	31	38	48	23	21 5	71 8
51	46	67 0	25 2	46	24 19	32	36	69 17	52	70 2	22 8	46	24	30
52	26 9	27	25	68 12	41	57	57	42	23 12	26	28	71 9	43	52
53	32	54	47	39	25 2	69 23	24 17	70 7	32	50	47	33	22 1	72 15
54	54	68 22	26 9	69 6	23	50	37	33	52	71 15	23 6	57	19	39
55	27 16	51	30	34	44	70 17	57	59	24 11	41	24	72 22	37	73 2
56	37	69 20	51	70 2	26 4	44	25 17	71 26	29	72 7	42	47	54	26
57	58	50	27 11	31	23	71 12	36	53	47	33	24 0	73 12	23 11	51
58	28 18	70 20	31	71 1	42	41	54	72 20	25 5	59	17	38	28	74 16
59	38	51	50	31	27 1	72 10	26 12	48	23	73 26	33	74 4	44	41
60	58	71 22	28 9	72 1	19	39	29	73 17	40	54	49	30	59	75 7
61	29 17	54	27	32	37	73 9	46	46	56	74 22	25 5	57	24 14	33
62	35	72 26	45	73 3	54	39	27 3	74 15	26 12	50	21	75 25	29	59
63	53	59	29 2	35	28 11	74 10	19	45	27	75 19	36	53	44	76 26
64	30 10	73 32	19	74 7	27	41	35	75 15	42	48	50	76 21	58	53
65	27	74 5	35	39	42	75 12	50	45	57	76 17	26 4	49	25 11	77 20
66	43	39	50	75 12	57	44	28 4	76 16	27 11	47	17	77 18	24	48
67	59	75 14	30 5	46	29 12	76 17	18	47	24	77 17	30	47	36	78 16
68	31 14	49	20	76 20	26	50	31	77 19	37	48	43	78 16	48	44
69	28	76 25	34	54	39	77 23	44	51	50	78 19	55	46	26 0	79 13
70	42	77 1	47	77 29	52	56	57	78 23	28 2	50	27 6	79 16	11	42
71	55	37	31 0	78 4	30 4	78 30	29 9	56	13	79 21	17	46	21	80 11
72	32 8	78 14	12	39	16	79 4	20	79 29	24	53	27	80 17	31	40
73	20	51	23	79 15	27	39	30	80 2	34	80 25	37	48	41	81 10
74	31	79 28	34	51	37	80 14	40	36	44	57	46	81 19	50	40
75	42	80 6	44	80 27	47	49	50	81 10	53	81 30	55	50	58	82 10
76	52	44	54	81 4	56	81 24	59	44	29 1	82 3	28 3	82 22	27 6	40
77	33 1	81 22	32 3	41	31 5	82 0	30 7	82 18	9	36	11	54	13	83 11
78	10	82 1	11	82 19	13	36	15	53	17	83 9	18	83 26	20	41
79	18	40	19	56	21	83 12	22	83 28	24	43	25	58	26	84 12
80	25	83 19	26	83 34	28	48	29	84 3	30	84 16	31	84 30	32	43
81	32	59	32	84 12	34	84 25	35	38	36	50	37	85 3	37	85 15
82	38	84 38	38	50	39	85 2	40	85 13	41	85 24	42	35	42	46
83	43	85 18	43	85 28	44	39	45	49	45	58	46	86 8	46	86 18
84	47	58	48	86 7	48	86 16	49	86 24	49	86 33	50	41	50	49
85	51	86 38	52	46	52	53	52	87 0	52	87 7	53	87 14	53	87 21
86	54	87 18	55	87 24	55	87 30	55	36	55	42	55	47	56	52
87	57	59	57	88 3	57	88 8	57	88 12	57	88 16	57	88 20	58	88 24
88	59	88 39	59	42	59	45	59	48	59	51	59	53	59	56
89	34 0	89 19	33 0	89 21	32 0	89 23	31 0	89 24	30 0	89 25	29 0	89 27	28 0	89 28
90	0	90 0	0	90 0	0	90 0	0	90 0	0	90 0	0	90 0	0	90 0

b	a = 63°		a = 64°		a = 65°		a = 66°		a = 67°		a = 68°		a = 69°	
	K	Q	K	Q	K	Q	K	Q	K	Q	K	Q	K	Q
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
0	0 0	63 0	0 0	64 0	0 0	65 0	0 0	66 0	0 0	67 0	0 0	68 0	0 0	69 0
1	27	0	26	0	25	0	24	0	23	0	22	0	22	0
2	54	1	53	1	51	1	49	1	47	1	45	1	43	1
3	1 22	2	1 19	2	1 16	2	1 13	2	1 10	2	1 7	2	1 5	2
4	49	3	45	3	41	3	38	3	34	3	30	3	26	3
5	2 16	5	2 11	5	2 7	5	2 2	5	57	5	52	5	47	4
6	43	7	38	7	32	7	26	7	2 20	7	2 15	7	2 9	6
7	3 10	10	3 4	10	57	10	50	9	44	9	37	9	30	8
8	37	13	30	13	3 22	13	3 15	12	3 7	12	59	12	52	11
9	4 4	17	56	17	47	16	39	16	30	15	3 22	15	3 13	14
10	31	21	4 22	21	4 12	20	4 3	20	53	19	44	18	34	17
11	58	26	48	25	37	24	27	24	4 16	23	4 6	22	55	21
12	5 25	31	5 14	30	5 2	29	51	28	39	27	28	26	4 16	25
13	52	36	40	35	27	34	5 15	33	5 2	32	50	31	37	29
14	6 18	42	6 5	40	52	39	39	38	25	37	5 12	36	58	34
15	45	48	31	46	6 17	45	6 3	44	48	42	34	41	5 19	39
16	7 11	54	56	53	41	51	26	50	6 11	48	56	47	40	45
17	38	64 1	7 22	65 0	7 6	58	50	56	34	54	6 17	53	6 1	51
18	8 4	9	47	7	30	66 5	7 13	67 3	56	68 1	39	59	22	57
19	30	17	8 12	15	54	12	37	10	7 19	8	7 0	69 6	42	70 3
20	56	25	37	23	8 18	20	8 0	18	41	15	22	13	7 3	10
21	9 22	34	9 2	31	42	28	23	26	8 3	23	43	20	23	17
22	48	43	27	40	9 6	37	46	34	25	31	8 4	28	43	24
23	10 13	52	52	49	30	46	9 9	43	47	39	25	36	8 3	32
24	39	65 2	10 16	59	54	56	31	52	9 9	48	46	44	23	40
25	11 4	13	41	66 9	10 17	67 6	54	68 2	30	57	9 7	53	43	49
26	29	24	11 5	20	41	16	10 16	12	52	69 7	27	70 2	9 2	58
27	54	35	29	31	11 4	26	38	22	10 13	17	48	12	22	71 7
28	12 19	47	53	42	27	37	11 0	32	34	27	10 8	22	41	17
29	43	59	12 16	54	50	49	22	43	55	38	28	32	10 0	27
30	13 7	66 11	40	67 6	12 12	68 1	44	55	11 16	49	48	43	19	37
31	31	24	13 3	19	34	13	12 6	69 7	37	70 0	11 8	54	38	47
32	55	38	26	32	56	25	27	19	57	12	27	71 5	57	58
33	14 19	52	49	45	13 18	38	48	31	12 17	24	46	17	11 15	72 9
34	43	67 6	14 12	59	40	52	13 9	44	37	37	12 5	29	33	21
35	15 6	21	34	68 13	14 2	69 6	30	58	57	50	24	41	51	33
36	29	36	56	28	23	20	50	70 12	13 17	71 3	43	54	12 9	45
37	52	51	15 18	43	44	34	14 10	26	36	16	13 2	72 7	27	57
38	16 14	68 7	40	59	15 5	49	30	40	55	30	20	20	45	73 10
39	36	24	16 1	69 15	26	70 5	50	55	14 14	44	38	34	13 2	23
40	58	41	22	31	46	21	15 9	71 10	33	59	56	48	19	37
41	17 20	58	43	48	16 6	37	28	26	51	72 14	14 14	73 2	36	51
42	41	69 16	17 4	70 5	26	53	47	42	15 9	29	31	17	53	74 5
43	18 2	34	24	22	45	71 10	16 6	58	27	45	48	32	14 9	19
44	23	52	44	40	17 4	27	25	72 14	45	73 1	15 5	48	25	34
45	44	70 11	18 4	58	23	45	43	31	16 2	18	22	74 3	41	49

b	a = 63° K	a = 63° Q	a = 64° K	a = 64° Q	a = 65° K	a = 65° Q	a = 66° K	a = 66° Q	a = 67° K	a = 67° Q	a = 68° K	a = 68° Q	a = 69° K	a = 69° Q
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
45	18 44	70 11	18 4	70 58	17 23	71 45	16 43	72 31	16 2	73 18	15 22	74 3	14 41	74 49
46	19 4	30	23	71 17	42	72 3	17 1	49	19	34	38	19	56	75 4
47	24	50	42	36	18 0	21	18	73 7	36	51	54	36	15 11	20
48	43	71 10	19 1	55	18	40	35	25	53	74 8	16 10	52	26	36
49	20 2	31	19	72 15	36	59	52	43	17 9	26	26	75 9	41	52
50	21	52	37	36	53	73 19	18 9	74 2	25	44	41	26	56	76 8
51	40	72 13	55	56	19 10	39	25	21	41	75 3	56	44	16 10	25
52	58	35	20 12	73 17	27	59	41	40	56	21	17 10	76 2	24	42
53	21 16	57	29	38	43	74 19	57	75 0	18 11	40	24	20	38	59
54	33	73 20	46	74 0	59	40	19 13	20	26	59	38	38	51	77 17
55	50	43	21 3	22	20 15	75 1	28	40	40	76 19	52	57	17 4	35
56	22 7	74 6	19	45	30	23	43	76 1	54	39	18 6	77 16	17	53
57	23	30	34	75 7	45	45	57	22	19 8	59	19	35	29	78 11
58	39	54	49	30	21 0	76 7	20 11	43	21	77 19	32	55	41	30
59	54	75 18	22 4	54	14	30	24	77 5	34	40	44	78 15	53	49
60	23 9	42	19	76 18	28	53	37	27	47	78 1	56	35	18 5	79 8
61	24	76 7	33	42	42	77 16	50	49	59	22	19 8	55	16	27
62	38	33	46	77 6	55	39	21 3	78 11	20 11	44	19	79 16	27	47
63	52	59	59	31	22 7	78 3	15	34	23	79 6	30	37	37	80 7
64	24 5	77 25	23 12	56	19	27	27	57	34	28	41	58	47	27
65	18	51	24	78 21	31	51	38	79 20	45	50	51	80 19	57	47
66	30	78 18	36	47	43	79 16	49	44	55	80 12	20 1	40	19 7	81 8
67	42	45	48	79 13	54	41	59	80 8	21 5	35	10	81 2	16	28
68	54	79 12	59	39	23 4	80 6	22 9	32	15	58	19	24	25	49
69	25 5	39	24 10	80 5	14	31	19	56	24	81 21	28	46	33	82 10
70	15	80 7	20	32	24	56	28	81 20	33	44	37	82 8	41	31
71	25	35	29	59	33	81 22	37	45	41	82 8	45	30	49	53
72	35	81 3	38	81 26	42	48	45	82 10	49	32	52	53	56	83 14
73	44	32	47	53	50	82 14	53	35	57	56	59	83 16	20 3	36
74	53	82 0	55	82 20	58	40	23 1	83 0	22 4	83 20	21 6	39	9	58
75	26 1	29	25 3	48	24 6	83 7	8	26	11	44	13	84 2	15	84 20
76	8	58	10	83 16	13	34	15	51	17	84 8	19	25	21	42
77	15	83 28	17	44	19	84 1	21	84 17	23	33	25	48	26	85 4
78	22	57	23	84 13	25	28	27	43	28	57	30	85 12	31	26
79	28	84 27	29	41	31	55	32	85 9	33	85 22	35	36	36	49
80	33	57	34	85 9	36	85 22	37	35	38	47	39	59	40	86 11
81	38	85 27	39	38	40	50	41	86 1	42	86 12	43	86 23	44	34
82	43	57	43	86 7	44	86 17	45	27	46	37	47	47	47	57
83	47	86 27	47	36	48	45	49	54	49	87 2	50	87 11	50	87 19
84	50	57	51	87 5	51	87 12	52	87 20	52	28	53	35	53	42
85	53	87 27	54	34	54	40	54	47	54	53	55	59	55	88 5
86	56	58	56	88 3	56	88 8	56	88 13	56	88 18	57	88 23	57	28
87	58	88 28	58	32	58	36	58	40	58	44	58	47	58	51
88	59	59	59	89 1	59	89 4	59	89 7	59	89 9	59	89 12	59	89 14
89	27 0	89 29	26 0	31	25 0	32	24 0	33	23 0	34	22 0	36	21 0	37
90	0	90 0	0	90 0	0	90 0	0	90 0	0	90 0	0	90 0	0	90 0

Table 13. Kelvin's Sumner Line Table

b	a = 70° K	a = 70° Q	a = 71° K	a = 71° Q	a = 72° K	a = 72° Q	a = 73° K	a = 73° Q	a = 74° K	a = 74° Q	a = 75° K	a = 75° Q	a = 76° K	a = 76° Q
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
0	0 0	70 0	0 0	71 0	0 0	72 0	0 0	73 0	0 0	74 0	0 0	75 0	0 0	76 0
1	21	0	20	0	19	0	18	0	17	0	16	0	15	0
2	41	1	39	1	37	1	35	1	33	1	31	1	29	0
3	1 2	2	59	2	56	1	53	1	50	1	47	1	44	1
4	22	3	1 18	3	1 14	2	1 10	2	1 6	2	1 2	2	58	2
5	43	4	38	4	33	4	28	4	23	3	18	3	1 13	3
6	2 3	6	57	6	51	6	45	5	39	5	33	5	27	4
7	23	8	2 17	8	2 9	8	2 3	7	56	7	49	6	41	6
8	44	11	36	10	28	10	20	9	2 12	9	2 4	8	56	8
9	3 4	14	55	13	46	13	37	12	28	11	19	10	2 10	10
10	24	17	3 15	16	3 5	16	55	15	45	14	35	13	25	12
11	45	20	34	19	23	19	3 12	18	3 1	17	50	16	39	15
12	4 5	24	53	23	41	22	29	21	17	20	3 5	19	53	18
13	25	28	4 12	27	59	26	46	25	33	23	20	22	3 7	21
14	45	33	31	31	4 17	30	4 3	29	49	27	35	25	21	24
15	5 5	38	50	36	35	34	20	33	4 5	31	50	29	35	27
16	25	43	5 9	41	53	39	37	37	21	35	4 5	33	49	31
17	44	49	28	46	5 11	44	54	42	37	40	20	38	4 3	35
18	6 4	55	46	52	29	49	5 11	47	53	45	35	42	17	40
19	24	71 1	6 5	58	46	55	28	52	5 9	50	50	47	31	44
20	43	7	24	72 4	6 4	73 1	44	58	25	55	5 5	52	45	49
21	7 3	14	42	11	21	7	6 1	74 4	40	75 1	19	57	59	54
22	22	21	7 0	18	39	14	17	10	56	7	34	76 3	5 12	59
23	41	29	18	25	56	21	34	17	6 11	13	48	9	26	77 4
24	8 0	37	36	32	7 13	28	50	24	26	19	6 3	15	39	10
25	19	45	54	40	30	35	7 6	31	41	26	17	21	52	16
26	38	53	8 12	48	47	43	22	38	56	33	31	27	6 5	22
27	56	72 2	30	56	8 4	51	38	46	7 11	40	45	34	18	28
28	9 15	11	48	73 5	21	59	54	54	26	48	59	41	31	35
29	33	20	9 5	14	37	74 8	8 9	75 2	41	55	7 13	48	44	42
30	51	30	22	24	53	17	25	10	55	76 3	26	56	57	49
31	10 9	40	39	34	9 9	26	40	19	8 10	11	40	77 4	7 10	56
32	27	51	56	44	25	36	55	28	24	20	53	12	22	78 4
33	44	73 2	10 13	54	41	46	9 10	37	38	29	8 6	20	34	11
34	11 2	13	30	74 4	57	56	25	46	52	38	19	28	46	19
35	19	24	46	15	10 13	75 6	39	56	9 6	47	32	37	58	27
36	36	36	11 2	26	28	16	54	76 6	19	56	45	46	8 10	36
37	53	48	18	37	43	27	10 8	17	33	77 6	58	55	22	44
38	12 9	74 0	34	49	58	38	22	27	46	16	9 10	78 4	34	53
39	26	12	50	75 1	11 13	50	36	38	59	26	22	14	46	79 2
40	42	25	12 5	13	28	76 1	50	49	10 12	37	34	24	57	11
41	58	38	20	26	42	13	11 4	77 0	25	47	46	34	9 8	21
42	13 14	52	35	39	56	26	17	12	38	58	58	44	19	30
43	29	75 6	50	52	12 10	38	30	24	50	78 9	10 10	55	30	40
44	44	20	13 4	76 5	24	51	43	36	11 2	21	22	79 5	41	50
45	59	34	18	19	38	77 4	56	48	14	32	33	16	51	80 0

b	a = 70° K	a = 70° Q	a = 71° K	a = 71° Q	a = 72° K	a = 72° Q	a = 73° K	a = 73° Q	a = 74° K	a = 74° Q	a = 75° K	a = 75° Q	a = 76° K	a = 76° Q
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
45	13 59	75 34	13 18	76 19	12 38	77 4	11 56	77 48	11 14	78 32	10 33	79 16	9 51	80 0
46	14 14	49	32	33	51	17	12 9	78 1	26	44	44	27	10 1	10
47	29	76 4	46	47	13 4	30	21	13	38	56	55	39	11	21
48	43	19	14 0	77 1	17	44	33	26	49	79 8	11 6	50	21	32
49	57	34	13	16	29	58	45	39	12 0	21	16	80 2	31	43
50	15 11	50	26	31	41	78 12	57	53	11	33	26	14	41	54
51	25	77 6	39	46	53	26	13 8	79 7	22	46	36	26	50	81 5
52	38	22	52	78 2	14 5	41	19	21	33	59	46	38	59	16
53	51	39	15 4	18	17	56	30	35	43	80 13	56	50	11 8	28
54	16 4	55	16	34	29	79 11	41	49	53	26	12 5	81 3	17	40
55	16	78 12	28	50	40	26	52	80 3	13 3	40	14	16	26	52
56	28	30	40	79 6	51	42	14 2	18	13	54	23	29	34	82 4
57	40	47	51	23	15 1	58	12	33	22	81 8	32	42	42	16
58	52	79 5	16 2	40	11	80 14	22	48	31	22	41	55	50	28
59	17 3	23	12	57	21	30	31	81 3	40	36	49	82 9	58	41
60	14	41	22	80 14	31	46	40	18	49	50	57	22	12 6	54
61	24	80 0	32	31	41	81 3	49	34	57	82 5	13 5	36	13	83 7
62	34	18	42	49	50	20	58	50	14 5	20	13	50	20	20
63	44	37	52	81 7	59	37	15 6	82 6	13	35	20	83 4	27	33
64	54	56	17 1	25	16 8	54	14	22	21	50	27	18	34	46
65	18 3	81 15	10	43	16	82 11	22	38	28	83 5	34	32	40	59
66	12	35	18	82 2	24	28	30	55	35	21	41	47	46	84 12
67	21	54	26	20	32	46	37	83 11	42	36	47	84 1	52	26
68	29	82 14	34	39	39	83 4	44	28	49	52	53	16	58	40
69	37	34	42	58	46	22	51	45	55	84 8	59	31	13 3	54
70	45	54	49	83 17	53	40	57	84 2	15 1	24	14 5	46	8	85 8
71	52	83 15	56	36	59	58	16 3	19	7	40	10	85 1	13	22
72	59	35	18 2	56	17 5	84 16	9	36	12	56	15	16	18	36
73	19 6	56	8	84 15	11	34	14	53	17	85 12	20	31	23	50
74	12	84 16	14	35	17	53	19	85 11	22	29	25	47	27	86 4
75	18	37	20	54	22	85 12	24	28	27	45	29	86 2	31	18
76	23	58	25	85 14	27	30	29	46	31	86 2	33	17	35	33
77	28	85 19	30	34	31	49	33	86 4	35	19	37	33	38	47
78	33	40	34	54	35	86 8	37	22	39	35	40	49	41	87 2
79	37	86 2	38	86 14	39	27	41	40	42	52	43	87 4	44	17
80	41	23	42	35	43	46	44	58	45	87 9	46	20	47	31
81	45	44	45	55	46	87 5	47	87 16	48	26	49	36	50	46
82	48	87 6	48	87 15	49	25	50	34	51	43	51	52	52	88 1
83	51	28	51	36	52	44	52	52	53	88 0	53	88 8	54	15
84	53	49	53	56	54	88 3	54	88 10	55	17	55	24	56	30
85	55	88 11	55	88 17	56	23	56	28	56	34	57	40	57	45
86	57	33	57	37	57	42	57	47	57	51	58	56	58	89 0
87	58	55	58	58	58	89 1	58	89 5	58	89 8	59	89 12	59	15
88	59	89 16	59	89 19	59	21	59	23	59	26	15 0	28	14 0	30
89	20 0	38	19 0	39	18 0	40	17 0	42	16 0	43	0	44	0	45
90	0	90 0	0	90 0	0	90 0	0	90 0	0	90 0	0	90 0	0	90 0

b	a = 77°		a = 78°		a = 79°		a = 80°		a = 81°		a = 82°		a = 83 °	
	K	Q	K	Q	K	Q	K	Q	K	Q	K	Q	K	Q
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
0	0 0	77 0	0 0	78 0	0 0	79 0	0 0	80 0	0 0	81 0	0 0	82 0	0 0	83 0
1	14	0	12	0	11	0	10	0	9	0	8	0	7	0
2	27	0	25	0	23	0	21	0	19	0	17	0	15	0
3	41	1	37	1	34	1	31	1	28	1	25	1	22	1
4	54	2	50	2	46	2	42	1	38	1	33	1	29	1
5	1 7	3	1 2	3	57	3	52	2	47	2	42	2	37	2
6	21	4	15	4	1 9	4	1 2	3	56	3	50	3	44	2
7	34	6	27	5	20	5	13	4	1 6	4	58	4	51	3
8	48	7	39	7	31	6	23	6	15	5	1 7	5	58	4
9	2 1	9	52	9	43	8	33	7	24	6	15	6	1 6	5
10	14	11	2 4	11	54	10	44	9	33	8	23	7	13	6
11	28	14	17	13	2 5	12	54	11	43	10	31	9	20	8
12	41	16	29	15	16	14	2 4	13	52	12	40	10	27	9
13	54	19	41	18	28	16	14	15	2 1	14	48	12	34	11
14	3 7	22	53	21	39	19	24	17	10	16	56	14	41	12
15	20	26	3 5	24	50	22	34	20	19	18	2 4	16	48	14
16	33	29	17	27	3 1	25	44	23	28	20	12	18	55	16
17	46	33	29	30	12	28	54	26	37	23	20	21	2 2	18
18	59	37	41	34	23	31	3 4	29	46	26	28	23	9	20
19	4 12	41	53	38	34	35	14	32	55	29	36	26	16	23
20	25	45	4 5	42	45	39	24	35	3 4	32	44	29	23	25
21	37	50	17	46	55	43	34	39	13	35	52	32	30	28
22	50	55	28	51	4 6	47	44	43	22	39	59	35	37	30
23	5 3	78 0	40	56	17	51	53	47	30	42	3 7	38	44	33
24	15	5	51	79 1	27	56	4 3	51	39	46	15	41	50	36
25	27	11	5 3	6	38	80 1	13	55	47	50	22	44	57	39
26	39	17	14	11	48	6	22	81 0	56	54	30	48	3 4	42
27	51	23	25	16	58	11	31	4	4 5	58	37	52	10	45
28	6 3	29	36	22	5 8	16	41	9	13	82 2	45	56	17	49
29	15	35	47	28	18	21	50	14	21	7	52	83 0	23	52
30	27	41	58	34	28	27	59	19	29	11	59	4	30	56
31	39	48	6 9	40	38	33	5 8	24	37	16	4 7	8	36	84 0
32	51	55	20	47	48	39	17	30	45	21	14	12	42	3
33	7 2	79 3	30	54	58	45	26	35	53	26	21	17	48	7
34	14	10	41	80 1	6 8	51	34	41	5 1	31	28	21	54	11
35	25	17	51	8	17	57	43	47	9	36	35	26	4 0	15
36	36	25	7 1	15	27	81 4	52	53	17	42	42	31	6	20
37	47	33	11	22	36	11	6 0	59	24	47	48	36	12	24
38	58	41	21	29	45	18	8	82 5	32	53	55	41	18	28
39	8 8	50	31	37	54	25	16	12	39	59	5 2	46	24	33
40	19	58	41	45	7 3	32	24	18	46	83 5	8	51	30	38
41	29	80 7	51	53	12	39	32	25	53	11	14	57	35	42
42	39	16	8 0	81 1	20	47	40	32	6 0	17	21	84 2	41	47
43	49	25	9	10	29	55	48	39	7	23	27	8	46	52
44	59	34	18	18	37	82 2	56	46	14	30	33	14	52	57
45	9 9	43	27	27	45	10	7 3	54	21	37	39	20	57	85 2

b	a = 77°		a = 78°		a = 79°		a = 80°		a = 81°		a = 82°		a = 83°	
	K	Q	K	Q	K	Q	K	Q	K	Q	K	Q	K	Q
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
45	9 9	80 43	8 27	81 27	7 45	82 10	7 3	82 54	6 21	83 37	5 39	84 20	4 57	85 2
46	19	53	36	36	53	19	11	83 1	28	43	45	26	5 2	7
47	28	81 3	45	45	8 1	27	18	9	34	50	51	32	7	13
48	37	13	53	54	9	35	25	16	41	57	56	38	12	18
49	46	23	9 2	82 4	17	44	32	24	47	84 4	6 2	44	17	24
50	55	33	10	13	24	53	39	32	53	11	7	50	21	29
51	10 4	44	18	23	32	83 2	45	40	59	18	13	57	26	35
52	13	55	26	33	39	11	52	48	7 5	26	18	85 3	31	41
53	21	82 6	34	43	46	20	58	57	11	33	23	10	35	46
54	29	17	41	53	53	29	8 4	84 5	16	41	28	17	40	52
55	37	28	48	83 3	9 0	38	10	13	22	49	33	23	44	58
56	45	39	55	13	6	48	16	22	27	56	38	30	48	86 4
57	53	50	10 2	24	13	57	22	31	32	85 4	42	37	52	10
58	11 0	83 1	9	34	19	84 7	28	40	37	12	47	44	56	17
59	7	13	16	45	25	17	34	49	42	20	51	52	6 0	23
60	14	25	23	56	31	27	39	58	47	28	55	59	4	29
61	21	37	29	84 7	37	37	44	85 7	52	37	59	86 6	7	36
62	28	49	35	18	42	47	49	16	57	45	7 3	13	11	42
63	34	84 1	41	29	47	57	54	25	8 1	53	7	21	14	49
64	40	13	46	41	52	85 8	59	35	5	86 2	11	28	17	55
65	46	25	52	52	57	18	9 4	44	9	10	15	36	20	87 2
66	52	38	57	85 4	10 2	29	8	54	13	19	19	44	23	8
67	57	51	11 2	15	7	39	12	86 4	17	28	22	51	26	15
68	12 2	85 3	7	27	11	50	16	13	21	36	25	59	29	22
69	7	16	12	39	15	86 1	20	23	24	45	28	87 7	32	29
70	12	29	16	51	19	12	24	33	27	54	31	15	35	36
71	17	42	20	86 3	23	23	27	43	30	87 3	34	23	37	43
72	21	55	24	15	27	34	30	53	33	12	37	31	39	50
73	25	86 8	28	27	31	45	33	87 3	36	21	39	39	42	57
74	29	22	32	39	34	56	36	13	39	30	41	47	44	88 4
75	33	35	35	51	37	87 7	39	23	42	39	43	55	46	11
76	37	48	38	87 3	40	18	42	33	44	48	45	88 3	48	18
77	40	87 2	41	16	43	30	45	44	46	58	47	11	49	25
78	43	15	44	28	46	41	47	54	48	88 7	49	20	51	32
79	46	29	47	41	48	53	49	88 4	50	16	51	28	52	39
80	48	42	49	53	50	88 4	51	15	52	25	53	36	54	47
81	50	56	51	88 6	52	15	53	25	54	35	54	44	55	54
82	52	88 10	53	18	54	27	54	36	55	44	55	53	56	89 1
83	54	23	55	31	55	39	55	46	56	54	56	89 1	57	9
84	56	37	56	44	56	50	56	57	57	89 3	57	10	58	16
85	57	51	57	56	57	89 2	57	89 7	58	13	58	18	58	23
86	58	89 5	58	89 9	58	13	58	18	59	22	59	26	59	31
87	59	18	59	22	59	25	59	28	59	31	59	35	59	38
88	13 0	32	12 0	34	11 0	37	10 0	39	9 0	41	8 0	43	7 0	45
89	0	46	0	47	0	48	0	49	0	50	0	52	0	53
90	0	90 0	0	90 0	0	90 0	0	90 0	0	90 0	0	90 0	0	90 0

b	a = 84°		a = 85°		a = 86°		a = 87°		a = 88°		a = 89°		a = 90°	
	K	Q	K	Q	K	Q	K	Q	K	Q	K	Q	K	Q
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
0	0 0	84 0	0 0	85 0	0 0	86 0	0 0	87 0	0 0	88 0	0 0	89 0	0 0	90 0
1	6	0	5	0	4	0	3	0	2	0	1	0	0	0
2	13	0	10	0	8	0	6	0	4	0	2	0	0	0
3	19	0	16	0	13	0	9	0	6	0	3	0	0	0
4	25	1	21	1	17	1	13	0	8	0	4	0	0	0
5	31	1	26	1	21	1	16	1	10	0	5	0	0	0
6	38	2	31	2	25	1	19	1	13	1	6	0	0	0
7	44	3	37	2	29	2	22	1	15	1	7	0	0	0
8	50	3	42	3	33	2	25	2	17	1	8	1	0	0
9	56	4	47	4	38	3	28	2	19	1	9	1	0	0
10	1 2	5	52	5	42	4	31	3	21	2	10	1	0	0
11	9	7	57	6	46	4	34	3	23	2	11	1	0	0
12	15	8	1 2	7	50	5	37	4	25	3	13	1	0	0
13	21	9	7	8	54	6	40	5	27	3	14	2	0	0
14	27	11	12	9	58	7	44	5	29	4	15	2	0	0
15	33	12	18	10	1 2	8	47	6	31	4	16	2	0	0
16	39	14	23	12	6	9	50	7	33	5	17	2	0	0
17	45	16	28	13	10	10	53	8	35	5	18	3	0	0
18	51	18	33	15	14	12	56	9	37	6	19	3	0	0
19	57	20	38	16	18	13	59	10	39	7	20	4	0	0
20	2 3	22	43	18	22	14	1 2	11	41	7	21	4	0	0
21	9	24	48	20	26	16	4	12	43	8	22	4	0	0
22	15	26	52	22	30	17	7	13	45	9	22	4	0	0
23	20	28	57	24	34	19	10	14	47	10	23	5	0	0
24	26	31	2 2	26	38	21	13	16	49	10	24	5	0	0
25	32	34	7	28	41	22	16	17	51	11	25	6	0	0
26	38	36	11	30	45	24	19	18	53	12	26	6	0	0
27	43	39	16	33	49	26	22	20	54	13	27	7	0	0
28	49	42	21	35	53	28	24	21	56	14	28	7	0	0
29	54	45	25	37	56	30	27	23	58	15	29	8	0	0
30	3 0	48	30	40	2 0	32	30	24	1 0	16	30	8	0	0
31	5	51	35	43	4	34	33	26	2	17	31	9	0	0
32	11	54	39	45	7	36	35	27	4	18	32	9	0	0
33	16	58	43	48	11	39	38	29	5	19	33	10	0	0
34	21	85 1	48	51	14	41	41	31	7	20	34	10	0	0
35	26	5	52	54	18	43	43	33	9	22	34	11	0	0
36	31	8	56	57	21	46	46	34	11	23	35	11	0	0
37	36	12	3 0	86 0	24	48	48	36	12	24	36	12	0	0
38	41	16	5	3	28	51	51	38	14	25	37	13	0	0
39	46	20	9	7	31	53	53	40	16	27	38	14	0	0
40	51	24	13	10	34	56	56	42	17	28	39	14	0	0
41	56	28	17	13	37	59	58	44	19	29	39	15	0	0
42	4 1	32	21	17	41	87 2	2 0	46	20	31	40	15	0	0
43	5	36	25	20	44	4	3	48	22	32	41	16	0	0
44	10	41	28	24	47	7	5	50	23	34	42	17	0	0
45	14	45	32	28	50	10	7	53	25	35	43	18	0	0

b	a = 84° K	a = 84° Q	a = 85° K	a = 85° Q	a = 86° K	a = 86° Q	a = 87° K	a = 87° Q	a = 88° K	a = 88° Q	a = 89° K	a = 89° Q	a = 90° K	a = 90° Q
°	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′	° ′
45	4 14	85 45	3 32	86 28	2 50	87 10	2 7	87 53	1 25	88 35	0 43	89 18	0 0	90 0
46	19	49	36	31	53	13	9	55	26	37	43	18	0	0
47	23	54	39	35	55	16	12	57	28	38	44	19	0	0
48	27	59	43	39	58	19	14	59	29	40	45	20	0	0
49	31	86 3	46	43	3 1	22	16	88 2	31	41	45	21	0	0
50	35	8	50	47	4	26	18	4	32	43	46	21	0	0
51	39	13	53	51	7	29	20	7	33	44	46	22	0	0
52	43	18	56	55	9	32	22	9	35	46	47	23	0	0
53	47	23	59	59	12	35	24	12	36	48	48	24	0	0
54	51	28	4 2	87 3	14	39	26	14	37	49	49	25	0	0
55	55	33	5	8	17	42	27	17	38	51	49	26	0	0
56	58	38	8	12	19	46	29	19	39	53	50	26	0	0
57	5 2	43	11	16	21	49	31	22	41	55	50	27	0	0
58	5	49	14	21	24	53	33	25	42	56	51	28	0	0
59	8	54	17	25	26	56	34	27	43	58	51	29	0	0
60	11	87 0	20	30	28	88 0	36	30	44	89 0	52	30	0	0
61	14	5	22	34	30	3	37	33	45	2	52	31	0	0
62	17	11	25	39	32	7	39	35	46	4	53	32	0	0
63	20	16	27	44	34	11	40	38	47	5	53	33	0	0
64	23	22	30	48	36	15	42	41	48	7	54	34	0	0
65	26	27	32	53	38	18	43	44	49	9	54	35	0	0
66	29	33	34	58	39	22	44	47	50	11	55	36	0	0
67	31	39	36	88 3	41	26	46	50	50	13	55	37	0	0
68	34	45	38	7	42	30	47	53	51	15	56	38	0	0
69	36	51	40	12	44	34	48	55	52	17	56	38	0	0
70	38	56	42	17	46	38	49	58	53	19	56	39	0	0
71	40	88 2	44	22	47	42	50	89 1	53	21	56	40	0	0
72	42	8	45	27	48	46	51	4	54	23	57	41	0	0
73	44	14	47	32	50	50	52	7	55	25	57	42	0	0
74	46	20	49	37	51	54	53	10	55	27	58	43	0	0
75	48	27	50	42	52	58	54	13	56	29	58	44	0	0
76	49	33	51	47	53	89 2	55	16	56	31	58	45	0	0
77	51	39	52	52	54	6	55	19	57	33	58	46	0	0
78	52	45	53	57	55	10	56	23	57	35	59	47	0	0
79	53	51	54	89 3	56	14	57	26	58	37	59	49	0	0
80	54	57	55	8	56	18	57	29	58	39	59	50	0	0
81	55	89 3	56	13	57	22	58	32	59	41	59	51	0	0
82	56	10	57	18	58	27	58	35	59	43	59	52	0	0
83	57	16	58	23	58	31	59	38	59	45	1 0	53	0	0
84	58	22	58	29	59	35	59	41	59	47	0	54	0	0
85	59	29	59	34	59	39	59	44	2 0	50	0	55	0	0
86	59	35	59	39	59	43	3 0	47	0	52	0	56	0	0
87	6 0	41	5 0	44	4 0	47	0	51	0	54	0	57	0	0
88	0	47	0	50	0	52	0	54	0	56	0	58	0	0
89	0	54	0	55	0	56	0	57	0	58	0	59	0	0
90	0	90 0	0	90 0	0	90 0	0	90 0	0	90 0	0	90 0	0	0

Table 14. Sumner Intersection

Larger Bearing	Smaller Bearing 2°	4°	6°	8°	10°
34°	0.07	0.14	0.22	0.32	0.43
36	.06	.13	.21	.30	.40
38	.06	.12	.20	.28	.37
40	.06	.12	.19	.26	.35
42	.05	.11	.18	.25	.33
44	.05	.11	.17	.24	.31
46	.05	.10	.16	.23	.30
48	.05	.10	.16	.22	.28
50	.05	.10	.15	.21	.27
52	.05	.09	.15	.20	.26
54	.04	.09	.14	.19	.25
56	.04	.09	.14	.19	.24
58	.04	.09	.13	.18	.23
60	.04	.08	.13	.18	.23
62	.04	.08	.13	.17	.22
64	.04	.08	.12	.17	.21
66	.04	.08	.12	.16	.21
68	.04	.08	.12	.16	.20
70	.04	.08	.12	.16	.20
72	.04	.08	.11	.15	.20
74	.04	.07	.11	.15	.19
76	.04	.07	.11	.15	.19
78	.04	.07	.11	.15	.19
80	.04	.07	.11	.15	.18
82	.04	.07	.11	.14	.18
84	.04	.07	.11	.14	.18
86	.04	.07	.11	.14	.18
88	.04	.07	.11	.14	.18
90	.03	.07	.11	.14	.18
92	.03	.07	.10	.14	.18
94	.03	.07	.10	.14	.17
96	.03	.07	.10	.14	.17
98	.04	.07	.10	.14	.17
100	.04	.07	.11	.14	.17
102	.04	.07	.11	.14	.17
104	.04	.07	.11	.14	.17
106	.04	.07	.11	.14	.17
108	.04	.07	.11	.14	.18
110	.04	.07	.11	.14	.18
112	.04	.07	.11	.14	.18
114	.04	.07	.11	.15	.18
116	.04	.07	.11	.15	.18
118	.04	.08	.11	.15	.18
120	.04	.08	.11	.15	.18
122	.04	.08	.12	.15	.19
124	.04	.08	.12	.16	.19
126	.04	.08	.12	.16	.19
128	.04	.08	.12	.16	.20
130	.04	.09	.13	.17	.20
132	.05	.09	.13	.17	.20
134	.05	.09	.13	.17	.21
136	.05	.09	.14	.18	.21
138	.05	.10	.14	.18	.22
140	.05	.10	.15	.19	.23
142	.05	.10	.15	.19	.23
144	.06	.11	.16	.20	.24
146	.06	.12	.16	.21	.25
148	.06	.12	.17	.22	.26
150	.07	.12	.18	.23	.27
152	.07	.13	.19	.24	.28
154	.07	.14	.20	.25	.30
156	.08	.15	.21	.26	.31
158	.09	.16	.22	.28	.33
160	.09	.17	.24	.30	.35

Larger Bearing	Smaller Bearing 12°	14°	16°	18°	20°
42°	0.42	0.52	0.63	0.76	0.91
44	.39	.48	.59	.70	.84
46	.37	.46	.55	.66	.78
48	.35	.43	.52	.62	.73
50	.34	.41	.49	.58	.68
52	.32	.39	.47	.55	.65
54	.31	.38	.45	.52	.61
56	.30	.36	.43	.50	.58
58	.29	.35	.41	.48	.56
60	.28	.34	.40	.46	.53
62	.27	.33	.38	.44	.51
64	.26	.32	.37	.43	.49
66	.26	.31	.36	.42	.48
68	.25	.30	.35	.40	.46
70	.24	.29	.34	.39	.45
72	.24	.28	.33	.38	.43
74	.23	.28	.32	.37	.42
76	.23	.27	.32	.36	.41
78	.23	.27	.31	.36	.40
80	.22	.26	.31	.35	.39
82	.22	.26	.30	.34	.39
84	.22	.26	.30	.34	.38
86	.22	.25	.29	.33	.37
88	.21	.25	.29	.33	.37
90	.21	.25	.29	.32	.36
92	.21	.25	.28	.32	.36
94	.21	.25	.28	.32	.36
96	.21	.24	.28	.32	.35
98	.21	.24	.28	.31	.35
100	.21	.24	.28	.31	.35
102	.21	.24	.28	.31	.35
104	.21	.24	.28	.31	.34
106	.21	.24	.28	.31	.34
108	.21	.24	.28	.31	.34
110	.21	.24	.28	.31	.34
112	.21	.24	.28	.31	.34
114	.21	.24	.28	.31	.34
116	.21	.25	.28	.31	.34
118	.22	.25	.28	.31	.35
120	.22	.25	.28	.32	.35
122	.22	.25	.29	.32	.35
124	.22	.26	.29	.32	.35
126	.23	.26	.29	.32	.36
128	.23	.26	.30	.33	.36
130	.23	.27	.30	.33	.36
132	.24	.27	.31	.34	.37
134	.24	.28	.31	.34	.37
136	.25	.28	.32	.35	.38
138	.26	.29	.32	.36	.39
140	.26	.30	.33	.36	.39
142	.27	.31	.34	.37	.40
144	.28	.32	.35	.38	.41
146	.29	.33	.36	.39	.42
148	.30	.34	.37	.40	.43
150	.31	.35	.38	.42	.45
152	.32	.36	.40	.43	.46
154	.34	.38	.41	.44	.48
156	.35	.39	.43	.46	.49
158	.37	.41	.45	.48	.51
160	.39	.43	.47	.50	.53
162	.41	.46	.49	.52	.56
164	.44	.48	.52	.55	.58
166	.47	.52	.55	.58	.61
168	.50	.55	.59	.62	.65

Larger Bearing	Smaller Bearing 22°	24°	26°	28°	30°
54°	0.71	0.81	0.93	1.07	1.23
56	.67	.77	.88	1.00	1.14
58	.64	.73	.83	0.94	1.07
60	.61	.69	.78	.89	1.00
62	.58	.66	.75	.84	0.94
64	.56	.63	.71	.80	.89
66	.54	.61	.68	.76	.85
68	.52	.59	.66	.73	.81
70	.50	.57	.63	.70	.78
72	.49	.55	.61	.68	.75
74	.48	.53	.59	.65	.72
76	.46	.52	.57	.63	.70
78	.45	.50	.56	.61	.67
80	.44	.49	.54	.60	.65
82	.43	.48	.53	.58	.63
84	.42	.47	.52	.57	.62
86	.42	.46	.51	.55	.60
88	.41	.45	.50	.54	.59
90	.40	.45	.49	.53	.58
92	.40	.44	.48	.52	.57
94	.39	.43	.47	.51	.56
96	.39	.43	.47	.51	.55
98	.39	.42	.46	.50	.54
100	.38	.42	.46	.49	.53
102	.38	.42	.45	.49	.53
104	.38	.41	.45	.48	.52
106	.38	.41	.45	.48	.52
108	.38	.41	.44	.48	.51
110	.37	.41	.44	.47	.51
112	.37	.41	.44	.47	.50
114	.37	.41	.44	.47	.50
116	.38	.41	.44	.47	.50
118	.38	.41	.44	.47	.50
120	.38	.41	.44	.47	.50
122	.38	.41	.44	.47	.50
124	.38	.41	.44	.47	.50
126	.39	.42	.45	.47	.50
128	.39	.42	.45	.48	.50
130	.39	.42	.45	.48	.51
132	.40	.43	.46	.48	.51
134	.40	.43	.46	.49	.52
136	.41	.44	.47	.49	.52
138	.42	.45	.47	.50	.53
140	.42	.45	.48	.51	.53
142	.43	.46	.49	.51	.54
144	.44	.47	.50	.52	.55
146	.45	.48	.51	.53	.56
148	.46	.49	.52	.54	.57
150	.48	.50	.53	.55	.58
152	.49	.52	.54	.57	.59
154	.50	.53	.56	.58	.60
156	.52	.55	.57	.60	.62
158	.54	.57	.59	.61	.63
160	.56	.59	.61	.63	.65
162	.58	.61	.63	.65	.67
164	.61	.63	.66	.68	.70
166	.64	.66	.68	.70	.72
168	.67	.69	.71	.73	.75
170	.71	.73	.75	.76	.78
172	.75	.77	.78	.80	.81
174	.80	.81	.83	.84	.85
176	.85	.87	.88	.89	.89
178	.92	.93	.93	.94	.94

Larger Bearing	Smaller Bearing 32°	34°	36°	38°	40°
62°	1.06	1.19	1.34	1.51	1.72
64	1.00	1.12	1.25	1.40	1.58
66	0.95	1.06	1.18	1.31	1.47
68	.90	1.00	1.11	1.23	1.37
70	.86	0.95	1.05	1.16	1.29
72	.82	.91	1.00	1.10	1.21
74	.79	.87	0.95	1.05	1.15
76	.76	.84	.91	1.00	1.09
78	.74	.80	.88	0.96	1.04
80	.71	.78	.85	.92	1.00
82	.69	.75	.82	.89	0.96
84	.67	.73	.79	.86	.93
86	.66	.71	.77	.83	.89
88	.64	.69	.75	.80	.86
90	.62	.67	.73	.78	.84
92	.61	.66	.71	.76	.82
94	.60	.65	.69	.74	.79
96	.59	.63	.68	.73	.78
98	.58	.62	.67	.71	.76
100	.57	.61	.65	.70	.74
102	.56	.60	.64	.68	.73
104	.56	.60	.63	.67	.72
106	.55	.59	.63	.66	.70
108	.55	.58	.62	.66	.69
110	.54	.58	.61	.65	.68
112	.54	.57	.61	.64	.68
114	.54	.57	.60	.63	.67
116	.53	.56	.60	.63	.66
118	.53	.56	.59	.63	.66
120	.53	.56	.59	.62	.65
122	.53	.56	.59	.62	.65
124	.53	.56	.59	.62	.65
126	.53	.56	.59	.62	.64
128	.53	.56	.59	.62	.64
130	.54	.56	.59	.62	.64
132	.54	.56	.59	.62	.64
134	.54	.57	.59	.62	.64
136	.55	.57	.60	.62	.65
138	.55	.58	.60	.63	.65
140	.56	.58	.61	.63	.65
142	.56	.59	.61	.63	.66
144	.57	.60	.62	.64	.66
146	.58	.60	.63	.65	.67
148	.59	.61	.63	.66	.68
150	.60	.62	.64	.66	.68
152	.61	.63	.65	.67	.69
154	.62	.65	.67	.68	.70
156	.64	.66	.68	.70	.72
158	.66	.67	.69	.71	.73
160	.67	.69	.71	.73	.74
162	.69	.71	.73	.74	.76
164	.71	.73	.75	.76	.78
166	.74	.75	.77	.78	.79
168	.76	.78	.79	.80	.82
170	.79	.80	.82	.83	.84
172	.82	.84	.85	.86	.86
174	.86	.87	.88	.89	.89
176	.90	.91	.91	.92	.93
178	.95	.95	.95	.96	.96

Larger Bearing	Smaller Bearing 42°	44°	46°	48°	50°
72°	1.34	1.48	1.64	1.83	2.04
74	1.26	1.39	1.53	1.70	1.88
76	1.20	1.31	1.44	1.58	1.75
78	1.14	1.24	1.36	1.49	1.63
80	1.09	1.18	1.28	1.40	1.53
82	1.04	1.13	1.22	1.33	1.45
84	1.00	1.08	1.17	1.26	1.37
86	0.96	1.04	1.12	1.21	1.30
88	.93	1.00	1.08	1.16	1.24
90	.90	0.97	1.04	1.11	1.19
92	.87	.93	1.00	1.07	1.14
94	.85	.91	0.97	1.03	1.10
96	.83	.88	.94	1.00	1.06
98	.81	.86	.91	0.97	1.03
100	.79	.84	.89	.94	1.00
102	.77	.82	.87	.92	0.97
104	.76	.80	.85	.90	.95
106	.74	.79	.83	.88	.92
108	.73	.77	.81	.86	.90
110	.72	.76	.80	.84	.88
112	.71	.75	.79	.83	.87
114	.70	.74	.78	.81	.85
116	.70	.73	.77	.80	.84
118	.69	.72	.76	.79	.83
120	.68	.72	.75	.78	.82
122	.68	.71	.74	.77	.81
124	.68	.71	.74	.77	.80
126	.67	.70	.73	.76	.79
128	.67	.70	.73	.75	.78
130	.67	.70	.72	.75	.78
132	.67	.70	.72	.75	.77
134	.67	.69	.72	.74	.77
136	.67	.70	.72	.74	.77
138	.67	.70	.72	.74	.77
140	.68	.70	.72	.74	.77
142	.68	.70	.72	.74	.77
144	.68	.71	.73	.75	.77
146	.69	.71	.73	.75	.77
148	.70	.72	.74	.76	.77
150	.70	.72	.74	.76	.78
152	.71	.73	.75	.77	.78
154	.72	.74	.76	.77	.79
156	.73	.75	.77	.78	.80
158	.74	.76	.78	.79	.81
160	.76	.77	.79	.80	.82
162	.77	.79	.80	.81	.83
164	.79	.80	.81	.83	.84
166	.81	.82	.83	.84	.85
168	.83	.84	.85	.86	.87
170	.85	.86	.87	.88	.88
172	.87	.88	.89	.90	.90
174	.90	.91	.91	.92	.92
176	.93	.93	.94	.94	.95
178	.96	.97	.97	.97	.97

Larger Bearing	Smaller Bearing 52°	54°	56°	58°	60°
82°	1.58	1.72	1.89	2.08	2.31
84	1.49	1.62	1.77	1.93	2.13
86	1.41	1.53	1.66	1.81	1.98
88	1.34	1.45	1.56	1.70	1.84
90	1.28	1.38	1.48	1.60	1.73
92	1.23	1.31	1.41	1.52	1.63
94	1.18	1.26	1.35	1.44	1.55
96	1.13	1.21	1.29	1.38	1.47
98	1.10	1.16	1.24	1.32	1.41
100	1.06	1.12	1.19	1.27	1.35
102	1.03	1.09	1.15	1.22	1.29
104	1.00	1.06	1.12	1.18	1.25
106	0.97	1.03	1.09	1.14	1.20
108	.95	1.00	1.05	1.11	1.17
110	.93	0.98	1.02	1.08	1.13
112	.91	.95	1.00	1.05	1.10
114	.89	.93	0.98	1.02	1.07
116	.88	.92	.96	1.00	1.04
118	.86	.90	.94	0.98	1.02
120	.85	.89	.91	.96	1.00
122	.84	.87	.90	.95	0.98
124	.83	.86	.90	.93	.96
126	.82	.85	.88	.91	.95
128	.81	.84	.87	.90	.93
130	.81	.83	.86	.89	.92
132	.80	.83	.85	.88	.91
134	.80	.82	.85	.87	.90
136	.80	.82	.84	.87	.89
138	.79	.81	.84	.86	.89
140	.79	.81	.83	.86	.88
142	.79	.81	.83	.85	.87
144	.79	.81	.83	.85	.87
146	.79	.81	.83	.85	.87
148	.79	.81	.83	.85	.87
150	.80	.81	.83	.85	.87
152	.80	.82	.83	.85	.87
154	.81	.82	.84	.85	.87
156	.81	.83	.84	.86	.87
158	.82	.83	.85	.86	.87
160	.83	.84	.85	.86	.88
162	.84	.85	.86	.87	.89
164	.85	.86	.87	.88	.89
166	.86	.87	.88	.89	.90
168	.88	.89	.90	.90	.91
170	.89	.90	.90	.91	.92
172	.91	.92	.91	.93	.93
174	.93	.93	.94	.95	.95
176	.95	.95	.96	.96	.96
178	.97	.98	.98	.98	.98

Larger Bearing	Smaller Bearing 62°	64°	66°	68°	70°
92°	1.77	1.91	2.08	2.28	2.51
94	1.67	1.80	1.95	2.12	2.31
96	1.58	1.70	1.83	1.97	2.14
98	1.50	1.61	1.72	1.85	2.00
100	1.43	1.53	1.63	1.75	1.88
102	1.37	1.46	1.55	1.66	1.77
104	1.32	1.40	1.48	1.58	1.68
106	1.27	1.34	1.42	1.51	1.60
108	1.23	1.29	1.37	1.44	1.53
110	1.19	1.25	1.32	1.39	1.46
112	1.15	1.21	1.27	1.33	1.40
114	1.12	1.17	1.23	1.29	1.35
116	1.09	1.14	1.19	1.25	1.31
118	1.07	1.11	1.16	1.21	1.26
120	1.04	1.08	1.13	1.18	1.23
122	1.02	1.06	1.10	1.15	1.19
124	1.00	1.04	1.08	1.12	1.16
126	0.98	1.02	1.05	1.09	1.13
128	.97	1.00	1.03	1.07	1.11
130	.95	0.98	1.02	1.05	1.09
132	.94	.97	1.00	1.03	1.06
134	.93	.96	0.99	1.01	1.04
136	.92	.95	.97	1.00	1.03
138	.91	.94	.96	0.99	1.01
140	.90	.93	.95	.97	1.00
142	.90	.92	.94	.96	0.99
144	.89	.91	.93	.96	.98
146	.89	.91	.93	.95	.97
148	.89	.90	.92	.94	.96
150	.88	.90	.92	.94	.95
152	.88	.90	.92	.93	.95
154	.88	.90	.91	.93	.94
156	.89	.90	.91	.93	.94
158	.89	.90	.91	.93	.94
160	.89	.90	.91	.93	.94
162	.90	.91	.92	.93	.94
164	.90	.91	.92	.93	.94
166	.91	.92	.93	.93	.94
168	.92	.93	.93	.94	.94
170	.93	.94	.94	.95	.95
172	.94	.95	.95	.96	.96
174	.95	.96	.96	.96	.97
176	.97	.97	.97	.97	.98
178	.98	.98	.99	.99	.99

Larger Bearing	Smaller Bearing 72°	74°	76°	78°	80°
102°	1.90	2.05	2.21	2.40	2.63
104	1.79	1.92	2.07	2.23	2.42
106	1.70	1.81	1.94	2.08	2.25
108	1.62	1.72	1.83	1.96	2.10
110	1.54	1.64	1.74	1.85	1.97
112	1.48	1.56	1.65	1.75	1.86
114	1.42	1.50	1.58	1.66	1.76
116	1.37	1.44	1.51	1.59	1.68
118	1.32	1.38	1.45	1.52	1.60
120	1.28	1.34	1.40	1.46	1.53
122	1.24	1.29	1.35	1.41	1.47
124	1.21	1.25	1.31	1.36	1.42
126	1.18	1.22	1.27	1.32	1.37
128	1.15	1.19	1.23	1.28	1.33
130	1.12	1.16	1.20	1.24	1.29
132	1.10	1.13	1.17	1.21	1.25
134	1.08	1.11	1.14	1.18	1.22
136	1.06	1.09	1.12	1.15	1.19
138	1.04	1.07	1.10	1.13	1.16
140	1.03	1.05	1.08	1.11	1.14
142	1.01	1.04	1.06	1.09	1.12
144	1.00	1.02	1.05	1.07	1.10
146	0.99	1.01	1.03	1.05	1.08
148	.98	1.00	1.02	1.04	1.06
150	.97	0.99	1.01	1.03	1.05
152	.97	.98	1.00	1.02	1.04
154	.96	.98	0.99	1.01	1.02
156	.96	.97	.99	1.00	1.01
158	.95	.97	.98	0.99	1.01
160	.95	.96	.98	.99	1.00
162	.95	.96	.98	.99	1.00
164	.95	.96	.98	.99	0.99
166	.96	.96	.98	.99	.99
168	.96	.96	.98	.99	.99
170	.97	.97	.98	.99	.99
172	.97	.97	.99	.99	.99
174	.98	.98	.99	.99	.99
176	.99	.98	.99	.99	.99
178	.99	.99	.99	.99	.99

Table 14. Sumner Intersection

Larger Bearing	Smaller Bearing 82°	84°	86°	88°	90°
112°	1.98	2.12	2.28	2.46	2.67
114	1.87	1.99	2.12	2.28	2.46
116	1.77	1.88	2.00	2.13	2.28
118	1.68	1.78	1.88	2.00	2.13
120	1.61	1.69	1.78	1.89	2.00
122	1.54	1.62	1.70	1.79	1.89
124	1.48	1.55	1.62	1.70	1.79
126	1.43	1.48	1.55	1.62	1.70
128	1.38	1.43	1.49	1.55	1.62
130	1.33	1.38	1.44	1.49	1.56
132	1.29	1.34	1.39	1.44	1.49
134	1.26	1.30	1.34	1.39	1.44
136	1.22	1.26	1.30	1.34	1.39
138	1.19	1.23	1.27	1.30	1.35
140	1.17	1.20	1.23	1.27	1.31
142	1.14	1.17	1.20	1.24	1.27
144	1.12	1.15	1.18	1.21	1.24
146	1.10	1.13	1.15	1.18	1.21
148	1.08	1.11	1.13	1.15	1.18
150	1.07	1.09	1.11	1.13	1.15
152	1.05	1.07	1.09	1.11	1.13
154	1.04	1.06	1.08	1.09	1.11
156	1.03	1.05	1.06	1.08	1.09
158	1.02	1.03	1.05	1.06	1.08
160	1.01	1.02	1.04	1.05	1.06
162	1.00	1.01	1.03	1.03	1.05
164	1.00	1.00	1.02	1.02	1.04
166	1.00	1.00	1.01	1.02	1.03
168	1.00	1.00	1.00	1.01	1.02
170	0.99	1.00	1.00	1.00	1.01
172	.99	1.00	1.00	1.00	1.01
174	.99	0.99	1.00	1.00	1.00
176	.99	.99	0.99	1.00	1.00
178	.99	.99	0.99	0.99	1.00

APPENDIX 1

COMPASS ADJUSTING

In Chapter IV we have assumed that the ship's compass will be properly compensated by a professional compass adjuster (p. 43), and that the navigator will thereafter only need to check the adjuster's table of small remaining deviations from time to time during the voyage. This occasional checking is accomplished most easily by observing the sun's azimuth at the same (or very nearly the same) time when a sextant altitude is measured in the regular work of navigating the ship (cf. p. 145).

But it may happen, expecially in the Navy, that the navigator will be his own compass adjuster: he may be required to swing ship (p. 43), and construct a complete table of deviations himself. To do this he will probably compare the sun's compass bearing with its true azimuth after swinging the ship's head successively on a number of different courses. Each time he observes the sun's bearing with a pelorus (p. 44) or other similar instrument, he will record the time by his watch, which should as usual be set to the ship's apparent time (p. 94). But no sextant observations of any kind will be needed; nor will the sun's altitude ordinarily be calculated. For this reason it is impossible to obtain the sun's true azimuth from our Table 11 p. 284) which requires a knowledge of the altitude, and which is merely intended for checking the compass error by an observation made nearly simultaneously with a sextant observation, as just explained.

For the purposes of the compass adjuster, the sun's true azimuth is most conveniently taken from Publication 71,

U. S. Hydrographic Office, often called the "red" azimuth table.[1] But if this is not available it can be obtained with almost equal ease, and without interpolation, from the Kelvin Table 13 (p. 292), the use of which is in this case greatly simplified because we only need the sun's azimuth, without a "computed altitude" (the K_3 of p. 129), and because the azimuth itself need only be correct to within a degree.

The given quantities of the problem are:

1. The sun's declination, to be taken to the nearest degree only, and without regard to its $+$ or $-$ sign;
2. The ship's known latitude, or D. R. latitude, always taken to the *nearest degree only*, and without regard to sign, except when choosing formulas;
3. The ship's apparent time, taken from the navigator's watch; counted for the present purpose in civil reckoning, A.M. or P.M. (pp. 75, 78); and hereafter called "the time."

We proceed as follows:[2]

OPERATION 1. Enter Table 13 with:

Arg. a_1 = declination,
Arg. b_1 = the time, if it is earlier in the morning than 6 A.M., or earlier in the afternoon than 6 P.M.;
Arg. b_1 = the time subtracted from 12^h, if later than 6, A.M. or P.M., and before use b_1 must be turned into degrees with Table 9 (p. 249). It need be correct to the nearest degree only; and it will always be less than 90°.

Then take from Table 13 the tabular angle K_1, also correct to the nearest degree only.

OPERATION 2. Enter Table 13 a second time with:

Arg. a_2 = the K_1 obtained in Operation 1.

Then, under this a_2, run down the K-column until you find the K_2 which comes nearest to the declination; and from the left-hand argument column take the b_2 which is in the

[1] In using this very extended table, the young navigator will note that the words "declination – same name as – latitude" signify that declination and latitude have the same sign, both $+$ or both $-$.

[2] This is a modification of the proceeding of p. 127.

same horizontal line with the declination K_2 just found in the K-column.

OPERATION 3. Add b_2 to the given latitude, and call it the *sum*. Also take the *difference*,[1] between b_2 and the latitude, subtracting the smaller from the larger. Then enter Table 13 a third time with:

Arg. $a_3 = K_1$, again as obtained in Operation 1.

(5′) Arg. $b_3 = 90° -$ above *sum*, if latitude and declination are of opposite signs, one + and one −.

(6′) Arg. $b_3 =$ above *sum* $- 90°$, if the time was later than 6 P.M. in the afternoon, or earlier than 6 A.M. in the morning.

(7′) Arg. $b_3 = 90° -$ above *difference*, in all other cases.

Then with the arguments a_3 and b_3, take from Table 13 the tabular Q_3, the sun's true azimuth, to the nearest degree. If the latitude is +, this azimuth Q_3 is to be counted from the north point of the horizon if we used formula (6′) just given; or if, in using formula (7′), b_2 was greater than the latitude; otherwise Q_3 is to be counted from the south point of the horizon. (If the latitude is −, interchange the north and south points of the horizon in these directions.[2]) And in all latitudes, the azimuth will of course be counted toward the east or west, according as the time was A.M. or P.M.

The foregoing will enable the navigator to obtain the sun's true azimuth from Table 13, either for compass adjusting purposes, or in case he should ever wish to know the azimuth when no altitude has been observed. The following are examples: Given:

1. Dec. = $+ 8°$; D. R. lat. = $+ 38°$; ship's apparent time = $4^h\ 10^m$, P.M.; ship's head by compass = 165°; observed bearing of sun = 240°.5.

[1] The *sum* and *difference* are not both needed; usually only one of the two will be written down.

[2] It will not usually be necessary to consider these directions about Q_3, because the navigator will generally know whether the sun bore N. or S. of the E. or W. point of the horizon at the time of observation.

Operation 1 gives $a_1 = 8°$; $b_1 = 4^h\ 10^m = 62\frac{1}{2}°$ (p. 249); $K_1 = 61°$(p. 295);
Operation 2 gives $a_2 = 61°$; $K_2 = 8°$; $b_2 = 17°$ (p. 308);
Operation 3 gives *sum* $= 55°$; *difference* $= 21°$; $a_3 = 61°$; $b_3 = 69°$; $Q_3 = 79°$; sun's azimuth = S 79° W = 259°.
The red tables, p. 88, give N 101° W. = 259°. Then by formula (2), p. 45, we have: $E = T - C = 259° - 240°.5 = +18°.5$ = compass error. And if we take the variation to be $+10°$, as on p. 48, we have by formula (1), p. 45, $D = E - V = 18°.5 - 10° = +8°.5$ = the deviation when the bearing of the ship's head by compass was 165°. This deviation is the same as is given in the table on p. 48.

2. Dec. $= -8°$; D. R. lat. $= +38°$; time $= 7^h\ 50^m$, A.M.; ship's head by compass $= 75°$; compass bearing of sun $= 114°$;
$a_1 = 8°$; $b_1 = 12^h - 7^h\ 50^m = 4^h\ 10^m = 62\frac{1}{2}°$; $K_1 = 61°$;
$a_2 = 61°$; $K_2 = 8°$; $b_2 = 17°$;
sum $= 55°$; *diff.* $= 21°$; $a_3 = 61°$; $b_3 = 35°$; $Q_3 =$ S 66°E = 114°.
The red tables also give 114° for the sun's azimuth, affording an excellent check on the work. Now the compass error $E = T - C = 114° - 114° = 0°$. With $V = +10°$, $D = E - V = 0° - 10° = -10°$. The table on p. 48 gives $D = -9°.7$.

3. Dec. $= +15°$; D. R. lat. $= +38°$; time $= 5^h\ 40^m$, A.M.; ship's head by compass $= 225°$; compass bearing of sun $= 39°$;
$a_1 = 15°$; $b_1 = 5^h\ 40^m = 85°$; $K_1 = 74°$;
$a_2 = 74°$; $K_2 = 15°$; $b_2 = 70°$;
sum $= 108°$; *diff.* $= 32°$; $a_3 = 74°$; $b_3 = 18°$; $Q_3 =$ N 75° E $= 75°$.
The red tables also give 75° for the sun's azimuth. And the compass error $E = T - C = 75° - 39° = 36°$. With $V = +10°$, $D = E - V = 36° - 10° = +26°$. The table on p. 48 gives $D = +25°.6$.

In this way the entire deviation table of p. 48 might have been obtained from observations, and the Second Deviation Table (p. 49) subsequently computed.

In connection with these two deviation tables, it may be of interest to supplement p. 49 by emphasizing once more that both tables are needed in correct navigation. The second table is necessary for changing a true course into a compass course for the helmsman (see p. 143 for an example): and the first table (in coastwise navigation) for correcting a re-

versed bearing (p. 55), or fixing a ship's position by cross bearings (p. 56). Only if the compass has been very well compensated or adjusted is it permissible to navigate with one table only. With a compass thus compensated the outstanding deviations would be so small that the two tables would be practically interchangeable. Were it possible to effect a perfect compensation, the two tables would be identical, and all the deviations of both would be 0°.

Having now explained the method of determining deviations without measuring or calculating the sun's altitude, we shall next consider in a practical way the principal problem of compass adjusting, or the placing of magnetic and other correctors in position, so as to minimize the deviation on all courses. We shall begin with certain definitions.

1. Semicircular deviation is that part of the total deviation which is corrected by two permanent magnets (or bundles of thin magnets) placed in the lower part of the binnacle. One of these permanent magnets is always placed in a fore-and-aft position, the other in a thwartship position. Both may be raised and lowered, so as to change their distances from the compass card. The north (or north-seeking) ends of all permanent magnets are always painted red.

2. Quadrantal deviation is that part of the total deviation which is corrected with two hollow iron spheres or other pieces of iron placed on each side of the compass bowl in an athwartship direction. They are adjustable in position, so that their distances from the compass card can be varied.

3. The heeling error is an additional deviation caused by the ship's rolling, and is corrected with an additional permanent magnet placed in a vertical position directly under the center of the compass bowl.

4. The following procedure may be used on a compass entirely uncompensated, or on a compass already approximately compensated, either by actual observations, or by the placing of magnets in approximate positions suggested

by experience. The method is specially designed to avoid the necessity of steering directly by the sun,[1] by ranges of known bearing, or by means of a "Napier diagram," in the course of the adjustment.

5. With the ship on an even keel and all permanent magnets being removed, begin by moving the vertical heeling magnet from top to bottom of its travel. This should not affect the compass card at all. If it does, the compass bowl is itself not properly centered in the binnacle, and its position there must be adjusted by the proper adjusting screws.

6. After the preliminary centering under 5, remove the heeling magnet to a distance, and place the two iron spheres in an approximately proper position, suggested by experience; or, if lacking experience, place them in the middle positions permitted by their respective ranges of adjustment.

7. Next you must learn how to head your ship on any desired *magnetic* course, say M. To do this, let G represent any convenient auxiliary number of degrees. In a steel ship, with compass entirely uncompensated, we might put $G = 15°$. In a wooden ship, or for a compass already approximately compensated, we might take $G = 10°$, or even less. In general, G should be about half as large as the largest remaining deviations the compass is expected to have.

Now steady the ship on the compass course $M - G$, and keep her steady on that course by heading for some object ashore, or by careful use of the compass. While running slowly on that course, observe the sun's compass bearing and note the ship's apparent time by your watch. The watch should be set in advance to ship's apparent time (see p. 94).

Then, with the red azimuth tables, or the Kelvin table, ascertain the true bearing of the sun, which we will call T, and calculate the compass error $E = T - (M - G)$. The variation, V, being taken from the chart, you will have the

[1] "Maneuver the ship with the helm until the sun comes on the sight vanes (of the pelorus)." Bowditch, p. 51, 1916 edition.

deviation $D = T - (M - G) - V$. Call this deviation d_1 (it corresponds to the compass course $M - G$).

Now steady the ship on a new compass course $M + G$, and determine by observation in exactly the same way a new deviation, which call d_2.

You will then have:

For ship's head by compass	the deviation
$M - G$,	d_1,
$M + G$,	d_2,

Then the deviation for the magnetic course M, which we desire to find, and which we will call d_M, will be:

$$d_M = \frac{G(d_2 + d_1)}{2\,G + d_2 - d_1};$$

And the required compass course, C_M, corresponding to the given magnetic course M, will be:

$$C_M = M - d_M.$$

The value of d_M may be taken from the accompanying little Table in all cases that are likely to arise in actual work. Should a number ever be required from a blank place in the Table, the compass probably has unusual deviations, and a preliminary partial compensation should be attempted by means of known ranges taken from a chart.

8. Go through the work under 7 for the magnetic course $M = 0°$ (or due north). If you take $G = 15°$, this will necessitate determining by observation the deviations d_1 and d_2 for the compass courses $0° - 15° = 345°$, and $0° + 15° = 15°$ (see example, p. 333).

You will then calculate d_0 and C_0, the deviation and compass course corresponding to the magnetic course $0°$, using the above formula for d_M, which in this case is d_0; or you will take d_0 directly from the Table.

9. Steady your ship on this compass course C_0 (or magnetic course $M = 0°$), and keep her quite steady by heading for a visible fixed point like a light-house, or by using tem-

Values of d_M, the Deviation for the Magnetic Course M

$G = 15°$

d_1, Dev'n for Com. Course $M-G$.	d_2, the Deviation for the Compass Course $M+G$: −30°	−25°	−20°	−15°	−10°	−5°	0°	+5°	+10°	+15°	+20°	+25°	+30°
−30°	−30°	−24°	−19°	−15°	−12°	−10°	− 8°	− 6°	− 4°	− 3°	− 2°	− 1°	0°
−25	−33	−25	−19	−15	−12	− 9	− 7	− 5	− 4	− 2	− 1	0	+ 1
−20		−27	−20	−15	−11	− 8	− 6	− 4	− 2	− 1	0	+ 1	+ 2
−15		−30	−21	−15	−11	− 8	− 5	− 3	− 1	0	+ 1	+ 2	+ 3
−10			−22	−15	−10	− 6	− 4	− 2	0	+ 1	+ 2	+ 4	+ 4
− 5			−25	−15	− 9	− 5	− 2	0	+ 2	+ 3	+ 4	+ 5	+ 6
0			−30	−15	− 8	− 3	0	+ 2	+ 4	+ 5	+ 6	+ 7	+ 8
+ 5				−15	− 5	0	+ 3	+ 5	+ 6	+ 8	+ 8	+ 9	+10
+10	+30			−15	0	+ 5	+ 8	+ 9	+10	+11	+11	+12	+12
+15	+15	+15	+15	0	+15	+15	+15	+15	+15	+15	+15	+15	+15
+20	+ 8	+ 5	0	−15			+30	+25	+22	+21	+20	+19	+19
+25	+ 3	0	− 5	−15					+35	+30	+27	+25	+23
+30	0	− 3	− 8	−15	−30							+33	+30

$G = 10°$

d_1, Dev'n for Com. Course $M-G$.	d_2, the Deviation for the Compass Course $M+G$: −30°	−25°	−20°	−15°	−10°	−5°	0°	+5°	+10°	+15°	+20°	+25°	+30°
−30°	−30°	−22°	−17°	−13°	−10°	− 8°	− 6°	− 5°	− 3°	− 2°	− 1°	− 1°	0°
−25	−37	−25	−18	−13	−10	− 8	− 6	− 4	− 3	− 2	− 1	0	+ 1
−20		−30	−20	−14	−10	− 7	− 5	− 3	− 2	− 1	0	+ 1	+ 1
−15			−23	−15	−10	− 7	− 4	− 3	− 1	0	+ 1	+ 2	+ 2
−10			−30	−17	−10	− 6	− 3	− 1	0	+ 1	+ 2	+ 3	+ 3
− 5				−20	−10	− 5	− 2	0	+ 1	+ 2	+ 3	+ 4	+ 4
0	+30			−30	−10	− 3	0	+ 2	+ 3	+ 4	+ 5	+ 6	+ 6
+ 5	+17	+20	+30		−10	0	+ 3	+ 5	+ 6	+ 7	+ 7	+ 8	+ 8
+10	+10	+10	+10	+10	0	+10	+10	+10	+10	+10	+10	+10	+10
+15	+ 6	+ 5	+ 3	0	−10		+30	+20	+17	+15	+14	+13	+13
+20	+ 3	+ 2	0	− 3	−10	−30			+30	+23	+20	+18	+17
+25	+ 1	0	− 2	− 5	−10	−20					+30	+25	+22
+30	0	− 1	− 3	− 6	−10	−17	−30						+30

$G = 5°$

d_1, Dev'n for Com. Course $M-G$.	d_2, the Deviation for the Compass Course $M+G$: −30°	−25°	−20°	−15°	−10°	−5°	0°	+5°	+10°	+15°	+20°	+25°	+30°
−30°	−30°	−18°	−12°	− 9°	− 7°	− 5°	− 4°	− 3°	− 2°	− 1°	− 1°	0°	0°
−25		−25	−15	−10	− 7	− 5	− 4	− 2	− 2	− 1	0	0	0
−20			−20	−12	− 8	− 5	− 3	− 2	− 1	− 1	0	0	+ 1
−15			−35	−15	− 8	− 5	− 3	− 2	− 1	0	+ 1	+ 1	+ 1
−10	+20	+35		−25	−10	− 5	− 2	− 1	0	+ 1	+ 1	+ 2	+ 2
− 5	+12	−15	+25		−15	− 5	− 2	0	+ 1	+ 2	+ 2	+ 2	+ 3
0	+ 8	+ 8	+10	+15		− 5	0	+ 2	+ 2	+ 3	+ 3	+ 4	+ 4
+ 5	+ 5	+ 5	+ 5	+ 5	+ 5	0	+ 5	+ 5	+ 5	+ 5	+ 5	+ 5	+ 5
+10	+ 3	+ 3	+ 2	+ 2	0	− 5		+15	+10	+ 8	+ 8	+ 7	+ 7
+15	+ 2	+ 2	+ 1	0	− 2	− 5	−15		−25	+15	+12	+10	+ 9
+20	+ 1	+ 1	0	− 1	− 2	− 5	−10	−25			+20	+15	+12
+25	+ 1	0	− 1	− 2	− 3	− 5	− 8	−15	−35			+25	+18
+30	0	− 1	− 1	− 2	− 3	− 5	− 8	−12	−20				+30

porarily an auxiliary compass. But this auxiliary compass must not be near enough to the magnets to be influenced by them.

10. Move the thwartship permanent correcting magnet toward or from the compass bowl, until the lubber line (p. 42) is on the correct magnetic course 0°. If you are working with a compass as yet entirely uncompensated, for which the permanent magnets have not even been placed in the binnacle, the thwartship one should be located with its red end to starboard, if the d_0 found under 8 was *plus*, or easterly deviation; and with its red end to port, if that d_0 was *minus*, or westerly deviation.

11. Go through the work under 7 again for the magnetic course $M = 90°$ (or due east). This will necessitate determining by observation the deviations for the compass courses 75° and 105°, if you are working with $G = 15°$. And you will calculate d_{90} and C_{90}, the deviation and compass course for the magnetic course 90°.

12. Now steady the ship on the compass course C_{90}, and place the fore-and-aft compensating permanent magnet with its red end forward, if the d_{90} found under 11 was *plus*, and with its red end aft, if d_{90} was *minus*. Adjust the magnet so as to make the compass read 90°. Your semicircular deviation is now corrected.

13. Go through the work under 7 for the magnetic course $M = 45°$ (or north-east, magnetic). This will necessitate observing the sun on the compass courses 30° and 60°; and will give you d_{45} and C_{45}, the deviation and compass course corresponding to magnetic course 45°.

14. Steady your ship on the compass course C_{45}, and move the two spheres in and out until the lubber line is on 45°, leaving the two spheres finally so placed that they are equally distant from the compass bowl. Your quadrantal deviation is now corrected.

15. To compensate for heeling error, head the ship approximately north or south, and keep her accurately on that

course by heading slowly for an object ashore. Now heel the vessel about 10°, by any convenient method.

If the north-seeking end of the compass card is thereby deviated toward the high side of the ship, place the heeling corrector with red end up in such a position as will bring the compass card back where it was before ship was heeled. If the compass card was deviated toward the low side of the ship, place the heeling corrector with the red end down.

16. The "Flinders bar" is a vertical bar of soft iron (or a combination of several bars) sometimes placed directly forward or aft of the compass. It will correct a certain part of the semicircular deviation not fully removed by the permanent magnets adjusted under 10 and 12. Usually a Flinders bar is best located by placing it in a position suggested by experience; but many compasses are adjusted without such a bar, and when there is none, the magnets usually need readjustment whenever the ship changes her latitude very considerably.

17. After completing the adjustment, it is well to swing ship on eight equidistant courses, and check the deviation table by new observations.

18. After a compass has once been adjusted, necessary minor changes of the magnets and spheres can be most conveniently made as follows. Head the ship north, and steady her with an auxiliary compass, or by means of a conspicuous object ashore. Then move the athwartship magnet up one inch, and note by the compass bearing of the sun how much the compass has changed, and in which direction. The same thing can be done with the fore-and-aft magnets by heading the ship east; and with the spheres by heading northeast. Having thus ascertained how much the compass is changed by a one-inch motion of each corrector, it is easy to calculate how much they should each be moved to compensate for any outstanding small deviations on the north, east, and northeast magnetic courses. Corrections can thus be made at any time during a voyage, if the deviations become unduly large.

When the magnets are not movable, but consist of fixed bundles of thin wire magnets, all adjustments throughout are made by increasing or diminishing the number of wires, instead of moving the magnets toward the compass bowl or away from it.

Notes

Note to 8. You can equally well head the ship south instead of north, and go through the work for $M = 180°$, instead of $M = 0°$.

Note to 10. If you head south, according to the Note to 8, the red end of the thwartship magnet must lie reversed.

Note to 11. This work may be done before that under 8, if desired.

Note to 12. You may head the ship west, if you wish, instead of east, and work for $M = 270°$, instead of 90°. The magnet must then be placed with red end aft, to correct *plus* deviation.

Note to 14. This may equally well be done for $M = 135°$, 225°, or 315°.

Note to 18. The above notes to 12 and 14 also apply to 18.

General Note. Whenever an adjustment can be made on two opposite courses, as indicated in the above Notes, accuracy will be increased by adjusting on *both* courses, and leaving the correctors finally in the average of the two positions found.

EXAMPLE

Consider the compass for which the two deviation tables (pp. 48, 49) hold good; and we shall suppose it to have been a totally uncompensated compass.

Under 8 and 7, putting $M = 0°$, $G = 15°$, we have:
for compass course $M - G = 345°$, $d_1 = -16°.0$ (table, p. 48),
for compass course $M + G = 15°$, $d_2 = -14°.9$ (table, p. 48).

$$\text{Then, } d_M = d_0 = \frac{G(d_2+d_1)}{2G+d_2-d_1} = \frac{15\times(-30.9)}{30-14.9+16.0} = -\frac{463.5}{31.1} = -14°.9.$$

This $-14°.9$ is in exact agreement with the d_0 given in the second deviation table (p. 49), for the magnetic course $M = 0°$. The

agreement would not always be as perfect. The $-14^\circ.9$ must now be corrected with the thwartship magnet as directed under 10.

Next, under 11, for $M = 90^\circ$, we have:
for compass course $M - G = 75^\circ$, $d_1 = -9^\circ.7$ (table, p. 48),
for compass course $M + G = 105^\circ$, $d_2 = -9^\circ.0$ (table, p. 48).

$$\text{Then, } d_M = d_{90} = \frac{G(d_2+d_1)}{2G+d_2-d_1} = \frac{15\times(-18.7)}{30-9.0+9.7} = -\frac{280.5}{30.7} = -9^\circ.1.$$

The $-9^\circ.1$ agrees closely with $-9^\circ.0$, given in the second deviation table (p. 49) for $M = 90^\circ$. It must be corrected as directed under 12. This completes the ordinary semicircular compensation.

Coming now to 13, with $M = 45^\circ$, we must observe the sun on the compass courses 30° and 60°. But the semicircular correction being now complete, the observed deviations will no longer agree with those given in the table, which are supposed to have been observed with a compass entirely uncompensated.

Let us suppose the observations gave the following results:

for compass course $M - G = 30^\circ$, $d_1 = +6^\circ.9$,
for compass course $M + G = 60^\circ$, $d_2 = +6^\circ.0$.

$$\text{Then, } d_M = d_{45} = \frac{G(d_2+d_1)}{2G+d_2-d_1} = \frac{15\times 12.9}{30+6.0-6.9} = +\frac{193.5}{29.1} = +6^\circ.6.$$

This $6^\circ.6$ must now be corrected as directed under 14, completing the quadrantal compensation.

APPENDIX 2

EX-MERIDIAN AND MISCELLANEOUS EXAMPLES

Ex-meridian observations (p. 99) are completely and accurately calculated with the Kelvin Table 13, working out a Sumner line (see p. 148 for an example). But if a rapid calculation of the ship's *latitude only* is desired, we may either use special tables (p 99, footnote), or, if these are not available, we may apply the Kelvin Table with but little additional labor and almost equal accuracy. We may still use the simplified method already explained in Appendix 1 (p. 324); except that Q_3 will not now be required, and K_2 as well as K_3 must be taken from the Table exact to the nearest minute (see Ex. 1). This having been done, the ship's latitude, *at the moment of observation,* may be quickly calculated from the ex-meridian altitude by first choosing from p. 89 the formula which would be appropriate for a noon-sight, and then applying to the D. R. latitude (*taken to the nearest degree only*) the two following corrections:

the "altitude correction" = corrected observed altitude $- K_3$;
the "declination correction" = sun's declination $- K_2$.

These corrections are to be added or subtracted, according as the formula chosen from p. 89 had a + or − sign for the altitude and declination respectively. This is the only use here made of the formula.

Young naval officers having commands should give special attention to the foregoing, because they may be required to signal their latitude to the flagship promptly at noon, before they have had time to calculate a noon-sight. In such cases an ex-meridian taken at about $11^h\ 30^m$, ship's apparent time,

and the resulting latitude *carried forward* to noon with the traverse table, will furnish an excellent value for the noon latitude to be signaled. The whole calculation, including the carrying forward to noon, can be completed in a few minutes, and the signal flags bent on, ready to be run up at noon precisely. The navigator will then be free to observe a noon-sight as a check.

As the noon longitude is always signaled as well as the latitude, a time-sight should be observed (if weather permits) in the early morning. This time-sight should be calculated as a Sumner long before noon; and the resulting Sumner line should be carried forward to noon by D. R. methods (p. 137), estimating in advance the probable speed of the ship and her course to noon. An ex-meridian observation made at about $11^h\ 30^m$ (and also carried forward) having furnished the noon latitude, the complete noon position of the ship will be finally fixed at that point of the moved Sumner line which cuts the ship's noon parallel of latitude (see Ex. 4). But when the navigator is not hurried by the necessity of signaling the ship's position at noon, it is better to work out a Sumner line from the morning time-sight, and also from a sight taken near noon (or at noon), and then determine the intersection point of the two Sumner lines in the regular way.

Ex. 1. Observed altitude, 26° 55′; index, + 3′; height of eye, 15 feet; watch time of observation, $11^h\ 42^m\ 0^s$ A.M.; D. R. latitude, to the nearest degree, 39°; D. R. longitude, 73° 58′; $C. - W.$, $4^h\ 51^m\ 42^s$; chron. slow, 4^s; equation, $+ 3^m\ 22^s$; declination, − 23° 24′; find the latitude by the ex-meridian method. (This is the example worked as a Sumner on pp. 148–149.)

The corrected observed altitude comes out 27° 8′; ship's apparent time, $11^h\ 41^m\ 16^s$ A.M.; $a_1 = 23°$; $b_1 = 18^m\ 44^s = 4°\ 41' = 5°$, to the nearest degree; $K_1 = 4°$;[1] $a_2 = 4°$;

[1] The value 4° is the nearest whole degree for K_1, since, in using Table 13, we notice that b_1 was only 4° 41′, and therefore not quite 5°. But our result would be almost as accurate if we continued the calculation with $K_1 = 5°$ (see also Ex. 11).

$K_2 = 22° \; 56'$ (taken out to the nearest minute); $b_2 = 23°$; $sum = 62°$; $b_3 = 90° - sum = 28°$; $a_3 = 4°$; $K_3 = 27° \; 56'$ (taken to the nearest minute). We choose formula (4), p. 89, or lat. = 90° − alt. − dec. The altitude correction is $27° \; 8' - 27° \; 56' = -48'$, which must be subtracted, because alt. is − in the formula. The declination correction is $23° \; 24' - 22° \; 56' = +28'$, which must also be subtracted, because dec. is also − in the formula. The D. R. latitude being 39°, the final latitude will be $39° - (-48') - 28' = 39° \; 20'$. On p. 149 we found 39° 19′ by the Sumner calculation.

Ex. 2. Corrected observed ex-meridian altitude, 74° 26′; ship's apparent time, $12^h \; 24^m$ P.M.; declination, + 3° 12′; D. R. latitude, + 17° 45′, or, to the nearest degree, + 18°. Find the latitude. *Ans.* 17° 39′.

Ex. 3.[1] Corrected observed ex-meridian altitude, 72° 3′; ship's apparent time, $11^h \; 46^m$ A.M.; declination, + 20° 30′; D. R. latitude, + 3° 5′; find the latitude. *Ans.* 2° 53′.

Ex. 4. At sea, at $9^h \; 42^m \; 28^s$ A.M, by the watch (see p. 146), a time-sight was observed, and worked as a Sumner. It gave a Sumner point in lat. 39° 50′ N., long. 73° 56′ W., bearing of line, 237°. The ship was estimated to be steaming at a speed of 15 knots on a true course of 182°. At $11^h \; 42^m$ an ex-meridian (see Ex. 1) gave the latitude 39° 20′. Find the latitude and longitude to be signalled *at noon.*

Ans. Sumner point carried forward to noon is then in lat. 39° 16′, long. 73° 58′; bearing of line unchanged at 237°.

[1] If the observed altitude is larger than 45°, it is well to be specially careful in taking out K_3. For instance, if K_1 happened to be $3\frac{1}{2}°$, a_2 as well as a_3 would also be $3\frac{1}{2}°$, and we might therefore take K_2 and K_3 from the column headed $a = 3°$ or the column headed $a = 4°$. In the case of sun observations the choice between the two columns will not matter for K_2, but for K_3 it is better to interpolate between the values given in the two adjoining columns in question (see Ex. 3).

It may also help the beginner in choosing between the *sum* and *difference* formulas of p. 325 to remember that the proper formula will always make b_3 come within a degree or two of the observed altitude in the case of ex-meridian observations.

The ex-meridian carried forward to noon gives the ship's noon latitude as 39° 15′ (to be signaled). So the latitude difference at noon between the ship and the Sumner point is 1′, and the bearing of the ship from the Sumner point is 237°.[1] For course 237° and lat. diff. 1′, the Traverse Table gives dep. = 1′.7. The corresponding long. diff. is 2′.2; and so the ship's long. at noon = 73° 58′ + 2′ = 74° 0′ (to be signaled).

Ex. 5. At sea, Sept. 20, 1918, A.M., with D. R. lat. 45° 26′ N.; D. R. long. 21° 40′ W.; at $7^h\ 58^m\ 26^s$, A.M. by the watch, the sun's measured altitude was 22° 7′; index, + 3′; height of eye, 26 feet; *C.* − *W.* was $1^h\ 26^m\ 20^s$ at 6^h A.M. Sept. 20, and $1^h\ 27^m\ 11^s$ at $9^h\ 26^m$ A.M. of the same date. The chronometer had been compared with a standard ashore, and found to be fast of G. M. T. $0^m\ 26^s$ on Sept. 1 at 10 A.M., and slow of G. M. T. $0^m\ 18^s$ on Sept. 15 at 4 P.M.

The 1918 almanac gives:

Sept. 19, 20^h G. M. T., decl., + 1° 22′.4; equation, + $6^m\ 17^s.2$.
Sept. 19, 22^h G. M. T., decl., + 1° 20′.5; equation, + $6^m\ 19^s.0$.
Sept. 20, 0^h G. M. T., decl., + 1° 18′.6; equation, + $6^m\ 20^s.7$.
Sept. 20, 2^h G. M. T., decl., + 1° 16′.6; equation, + $6^m\ 22^s.5$.

Find the longitude of the ship by the time-sight method. *Ans.* At the time of observation *C.* − *W.* was $1^h\ 26^m\ 49^s.4$; chronometer was slow $0^m\ 32^s.4$; the observation being a forenoon one, the G. M. T. came out $21^h\ 25^m\ 48^s$ of the 19th Sept. (p. 78); by formula (4), p. 100, hav. (24^h − T) was 9.38260; corresponding 24^h − T was $3^h\ 55^m\ 23^s$ (p. 264), and T was $20^h\ 4^m\ 37^s$ (p. 103, footnote); ship's longitude was 21° 52′ W.

Ex. 6. Simultaneously with the altitude measured in Ex. 5, the sun's compass bearing was taken with a pelorus and found to be 123°. The variation was 22° W., by the magnetic chart. Find the deviation. *Ans.* 11° E.

This example may be solved with Table 11 because the altitude has been measured.

Ex. 7. Using the data of Ex. 5, find the ship's noon latitude on Sept. 20, 1918, from a measured noon altitude of 45° 46′. *Ans.* 45° 18′.

Ex. 8. Calculate Ex. 5 as a Sumner by the Kelvin Table.

[1] This would be 237° − 180° if the ship's latitude had come out greater than that of the Sumner point.

Ans. The Sumner point is in latitude 45° 33′; longitude 21° 49′; bearing of the line 22° or 180° + 22°, according to the end of the line to be used.

Ex. 9. From the noon latitude of Ex. 7, and the Sumner line of Ex. 8, find the ship's noon longitude, assuming the ship was steaming at 17 knots on a 168° true course. *Ans.* 21° 2′.

Ex. 10. At sea, from an observation at $8^h\ 28^m$ A.M., ship's apparent time, a Sumner point was computed to be in latitude 28° 26′ N.; longitude 40° 11′ W.; bearing of the line 28° or 208°. Clouds having prevented observation at noon, the latitude was found from an ex-meridian observation to be 27° 17′ at $12^h\ 28^m$ P.M., ship's time. The ship was steaming at 18 knots on a 130° true course. Find the noon latitude and longitude. *Ans.* Latitude, 27° 22′; longitude, 39° 30′.

Ex. 11. With the data of Ex. 1, it is required to prepare in advance for an ex-meridian observation and its calculation.

Since it is intended to make the observation at about $11^h\ 40^m$, ship's time, we begin our preparatory calculations by computing K_2 and K_3 for $11^h\ 36^m$ and $11^h\ 44^m$,[1] ship's time, which correspond to $11^h\ 36^m\ 44^s$ and $11^h\ 44^m\ 44^s$ by the watch[2] We thus obtain:

for $11^h\ 36^m\ 44^s$, declination correction = − 28′, to be subtracted;
alt. correction = alt. − 26° 50′, to be subtracted.
for $11^h\ 44^m\ 44^s$, declination correction = + 28′, to be subtracted;
alt. correction = alt. − 27° 56′, to be subtracted.

This completes the preparatory calculation. In Ex. 1 the actual observation of altitude was made at $11^h\ 42^m$, and the corrected altitude was 27° 8′. Interpolating the declination and altitude corrections for $11^h\ 42^m$, we obtain:

declination correction = + 9′; alt. correction = 27° 8′ − 27° 34′ = − 26′;

both corrections to be subtracted. We then have, finally: Latitude = 39° − 9′ + 26′ = 39° 17′. In Ex. 1 we found 39° 20′, and on p. 149, 39° 19′.

[1] We have chosen 36^m and 44^m so as to have b_1 an exact number of degrees. This increases the accuracy of K_1 (cf. Ex. 1, p. 336, footnote).

[2] We know from the data of Ex. 1 that the watch was 44^s fast of ship's apparent time.

Ex. 12. With the data of Ex. 3, prepare in advance for the calculation. *Ans.* We find:
for $11^h\ 40^m$, declination correction, $-25'$, to be added,
alt. correction $=$ alt. $-71°\ 20'$, to be added;
for $11^h\ 48^m$, declination correction, $-28'$, to be added,
alt. correction $=$ alt. $-71°\ 46'$, to be added;
and for the final latitude $2°\ 52'$. In Ex. 3 we found $2°\ 53'$; but such small differences are not of much importance in navigation calculations.

Ex. 13. Using the data of Ex. 5 and Ex. 9, prepare in advance for the noon-sight of Ex. 7, and its speedy calculation.

Ans. D. R. longitude at noon, $21°\ 20'$; watch time of noon, $11^h\ 50^m\ 37^s$; declination at noon, $+1°\ 17'$; D. R. latitude at noon, $44°\ 20'$; formula (p. 89), lat. $= 90° +$ dec. $-$ alt. To get the approximate noon altitude in advance, we invert the formula, and thus obtain an approximate "D. R. alt." $= 90° +$ dec. $-$ D. R. lat. $= 90° + 1°\ 17' - 44°\ 20' = 46°\ 57'$. For this D. R. alt. at noon, we find that Table 6 + Table 7 $= +10'$. Therefore, at noon, lat. $= 90°$ $+$ dec. $- 10'$ $-$ observed alt. $-$ index correction, or noon lat. $= 91°\ 4'$ $-$ observed alt. $= 91°\ 4' - 45°\ 46' = 45°\ 18'$. This number ($91°\ 4'$) is often called the "constant." If it has been prepared in advance, the latitude can be calculated in a few moments, after the noon observation has been made at about $11^h\ 50^m\ 37^s$ by the watch.

Ex. 14. With declination $-3°\ 7'$; D. R. noon latitude $+38°\ 17'$; prepare a constant for a noon-sight, and calculate the latitude, supposing that the observed altitude turned out to be $48°\ 17'$, height of eye 20 feet, and index correction $+3'$. *Ans.* D. R. altitude, $48°\ 36'$; lat. $= 86°\ 39'$ $-$ obs'd alt. $= 38°\ 22'$.

Ex. 15. With the data of Ex. 13, and at $11^h\ 30^m$ by the watch, it is required to set it so that it will be correct at noon.

Ans. Move the hands forward from $11^h\ 30^m$ to $11^h\ 39^m\ 23^s$, as nearly as may be conveniently possible. (The second hand of a watch should always be set so as to be on 60^s when the minute hand is exactly on one of the minute divisions of the dial.)

Ex. 16. Prepare a constant for a meridian observation of β Cassiopeiæ, Dec. 20, 1917, and determine in advance the approximate time for the observation. D. R. latitude, 39° 18′ N., D. R. longitude, 33° 7′ W., both calculated for 8 P.M.; ship steaming 11 knots due E. by compass; variation, 24° W.; deviation, 3° E. Also calculate the latitude, supposing the observed altitude turned out to be 70° 54′, with eye 20 feet and index + 3′. *Ans.* Ship's time of observation, $6^h\ 11^m$ P.M.; lat. = obs'd alt − 31° 19′ = 70° 54′ − 31° 19′ = 39° 35′. The constant is 31° 19′.

Ex. 17. On the ship of Ex. 16, Dec. 20, 1917, at $6^h\ 38^m\ 23^s$ P.M. by the watch, the altitude of Aldebaran or α Tauri was measured, and found to be 33° 25′. *C. − W.* was $2^h\ 12^m\ 48^s$; chron. fast $2^m\ 26^s$. Find the longitude, using a D. R. latitude; and also run a Sumner line. (Note. The correction for "time past noon" in this example is $1^m\ 27^s$.) *Ans.* Longitude, 33° 13′ W.; Sumner point, latitude, 39° 15′; longitude, 33° 13′; bearing of the line, 6° or 180° + 6°.

Ex. 18. From the Sumner line of Ex. 17 and the latitude of Ex. 16 find the longitude at $6^h\ 11^m$, when the meridian observation was made. *Ans.* 33° 16′.

Ex. 19. A ship is to proceed (p. 19) from Sandy Hook (lat., 40° 28′ N.; long., 73° 50′ W.) to St. Vincent (lat., 16° 50′ N.; long., 25° 7′ W.). A straight line being drawn between these two points on the North Atlantic great circle sailing (or gnomonic) chart (p. 38), it was found to cross the successive principal longitude meridians at the following points:

A, lat., 39° 37′; long., 70° 0′; *B*, lat., 36° 39′; long., 60° 0′;
C, lat., 32° 34′; long., 50° 0′; *D*, lat., 27° 10′; long., 40° 0′;
E, lat., 20° 30′; long., 30° 0′.

The shortest track between Sandy Hook and St. Vincent will therefore pass through these successive points (see p. 38). It is required to calculate logarithmically, by middle latitude sailing (p. 35), the successive courses and distances between these points, so as to compare them with the middle latitude course and distance from Sandy Hook to St. Vincent direct. The middle latitude is to be taken to the nearest minute in each case. *Ans.*

	COURSE	DIST.
Sandy Hook to *A*	106° 9′	183.3
A to *B*	110° 40′	504.4
B to *C*	116° 23′	551.3
C to *D*	121° 55′	613.0
D to *E*	126° 5′	679.1
E to St. Vincent	128° 24′	354.2
Total distance by great circle sailing		2885.3

Middle latitude sailing, Sandy Hook to St. Vincent direct, course, 118° 56′	dist.	2931.0
Apparent saving of distance by great circle sailing,		45.7

It will thus be seen that the great circle course on leaving the Hook is more than a whole compass point to the northward of the middle latitude course, being 106° 9′, instead of 118° 56′.

Ex. 20. A sub-chaser with a cruising speed of 12 knots is bound from Norfolk to New York. While on the way, the navigator is required to find her true course and distance from a point off Winter Quarter Lightship (lat., 37° 54′; long., 74° 54′), to a point off N. E. End Lightship (lat., 38° 56′; long., 74° 27′), *assuming* that a $\frac{1}{2}$-knot flood-current set into the mouth of the Delaware in a N. W. direction during 3 hours of the run.

Ans. If the chaser shaped her course without regard to the tidal current, she would, after running down her distance, be $1\frac{1}{2}$ miles N. W. of her intended destination off N. E. End ship. To avoid this, her course should be shaped for a point $1\frac{1}{2}$ miles S.E. of her intended destination, and then the current will cause her to reach the original desired point. The easiest way to make the calculation is to use the method of traverse sailing (p. 39). This requires that we calculate the latitude difference and departure, separately, both for the ship's run and for the current, and then correct the former with the latter before taking from the traverse table the ship's final course and distance. We first calculate for the run from Winter Quarter to N. E. End, using the latitudes and longitudes given above, and obtain:

	Lat. Diff.	Dep.
For ship's run without regarding current	62.0, northerly;	21.2, easterly;
$1\frac{1}{2}$ miles, N.W. current	1.0, northerly;	1.0, westerly;
Subtracting the current effect .	61.0, northerly;	22.2, easterly;

and corresponding to latitude difference 61.0, departure 22.2, the Traverse Table gives true course for the ship 20°, distance 65 miles. The course without regard to current would have been 19°.

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